MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Earth Science Data and Information System (ESDIS)

Level 1 Product Generation System (LPGS)

Performance and Sizing Estimates

June 1997

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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1. Introduction

1.1 Scope

This document contains the approaches, assumptions, and results of performance and sizing estimates for the Earth Science Data and Information System (ESDIS) Level 1 Product Generation System (LPGS).

1.2 LPGS Overview

The LPGS is a source of Enhanced Thematic Mapper Plus (ETM+) Level 1 (L1) data within the ESDIS Ground System (EGS). The EGS is a collection of ground support elements for the Earth Observing System (EOS) and includes the EOS Data and Information System (EOSDIS), institutional support elements, affiliated and international partner data centers, international partner instrument control and operations centers, and other sources of data. The LPGS is located at the Earth Resources Observation System (EROS) Data Center (EDC) Distributed Active Archive Center (DAAC) and provides ETM+ L1 digital image generation and transfer services on a demand basis. The LPGS receives L1 digital image generation requests and distributes generated L1 digital images to customers through the EOSDIS Core System (ECS) at the EDC DAAC on a first in-first out (FIFO) basis.

The LPGS produces L1 data images in electronic format corresponding to a Worldwide Reference System (WRS) scene, floating scene center, or partial ETM+ subintervals of up to three WRS scene equivalents based on customer requests. The LPGS is capable of producing a daily volume equivalent to at least 25 WRS scenes of L1 radiometrically corrected and geometrically corrected images in any combination. The LPGS can create digital images projected to different coordinate reference systems, for any combination of the eight spectral channels collected by the ETM+ instrument, or in different output formats according to other options specified in the customer’s request. The Level 0 radiometrically corrected (L0R) data are requested from the EDC DAAC, and appended calibration parameter, payload correction data (PCD), and mirror scan correction data (MSCD) files are applied by the LPGS in producing L1 digital images.

The digital images created by the LPGS are provided, along with processing status, quality information (metadata), associated calibration parameter file (CPF), PCD, MSCD, and calibration data to the ECS, which distributes the entire L1 product to the customer.

2. Documentation

2.1 Applicable Documents

The information in the following documents was used to conduct the performance and sizing estimates for the LPGS:

1. NASA GSFC, 510-FPD/0196, *Level 1 Product Generation System (LPGS) Functional and Performance Requirements Specification*, February 1997
2. NASA GSFC, 510-3OCD/0296, *Level 1 Product Generation System (LPGS) Operations Concept*, February 1997
3. NASA GSFC, 510-4SDS/0196, *Level 1 Product Generation System (LPGS) System Design Specification*, March 1997
4. NASA GSFC, 430-11-06-007-0, *Landsat 7 0R Distribution Product Data Format Control Book (DFCB), HDF Version*, February 1997
5. NASA GSFC, 430-15-01-002-0, *Landsat 7 Calibration Parameter File Definition*, February 1997
6. NASA GSFC, 23007702-IVC, *Landsat 7 System Data Format Control Book (DFCB), Volume IV—Wideband Data*, April 1996
7. NASA GSFC, *Landsat 7 Image Assessment System (IAS) System Design Specification*, February 1997
8. *Radiometry Algorithm Descriptions* on the Web at URL http://ltpwww.gsfc.nasa.gov/LANDSAT/
9. *Landsat 7 Image Assessment System (IAS) Geometric Algorithm Theoretical Basis Document* on the Web at URL http://edcwww.cr.usgs/IAS
10. Silicon Graphics, *Origin 2000TM Technical Description* on the Web at URL http://www.sgi.com/
11. Storey, J., February 18, 1997 memorandum to J. Henegar summarizing IAS benchmark sizing and analysis conducted at EDC
12. Davis, B., May 9, 1997 E-mail to W. Wang summarizing preliminary TMRESAMPLE timing information
13. *Benchmark Results* on the Web at URL http://performance.netlib.org/performance/html/PDStop.html

2.2 Reference Documents

The following document was used for background information.

EDC IAS Turnover Materials

3. LPGS Performance Requirements

The following are the performance requirements for the LPGS hardware, software, and workload scenarios:

Requirement 4.1.1 The LPGS shall be capable of processing a volume of data equivalent to 28 (accounts for 10 percent LPGS internal reprocessing) standard L0R WRS scenes to Level 1 digital images each day.

Requirement 4.1.4 The LPGS shall provide at least 110 percent of the processing throughput capability required to satisfy the worst-case processor loading.

Requirement 4.1.5 The LPGS shall provide at least 125 percent of the random access memory capacity required to satisfy the worst case memory loading.

Requirement 4.1.6 The LPGS shall provide at least 125 percent of the peripheral storage capacity required to satisfy the worst case peripheral storage loading.

Requirement 4.2.1 The LPGS shall be able to ingest from ECS a data volume equivalent to three WRS scenes worth of standard L0R data for each Level 1 digital image request.

Requirement 4.2.2 The LPGS shall have the capability to support the transfer to ECS of the equivalent of a minimum of 25 WRS sized Level 1 digital images per day .

Requirement 4.2.3 The LPGS-ECS interface shall provide the capability to transfer to the ECS at least 33 GB of Level 1 output files per day.

4. Modeling Approaches

This section details the approaches used to model the LPGS hardware, process flow, and workload.

4.1 Hardware Configuration

The LPGS hardware configuration is shown in Figure 4–1. A stripped-down version of the hardware configuration used for modeling is shown in Figure 4–2. Only the L1 processing hardware configuration item (HWCI) and quality assessment (QA)/anomaly analysis (AA) HWCI are considered for the modeling. The internal network HWCI, Operations Interface HWCI, and Printer HWCI are excluded for this modeling study. The L1 Processing HWCI is for the L1 product generation and storage. It is assumed that the visual assessment of data quality for the automatic QA will be done on the workstation in this HWCI. For the non-nominal processing (anomaly analysis), processing of data will be done on the L1 Processing HWCI but the manual analysis and visual assessment of the images (for both benchmark work order and diagnostic work order) will be done on the QA/AA HWCI.

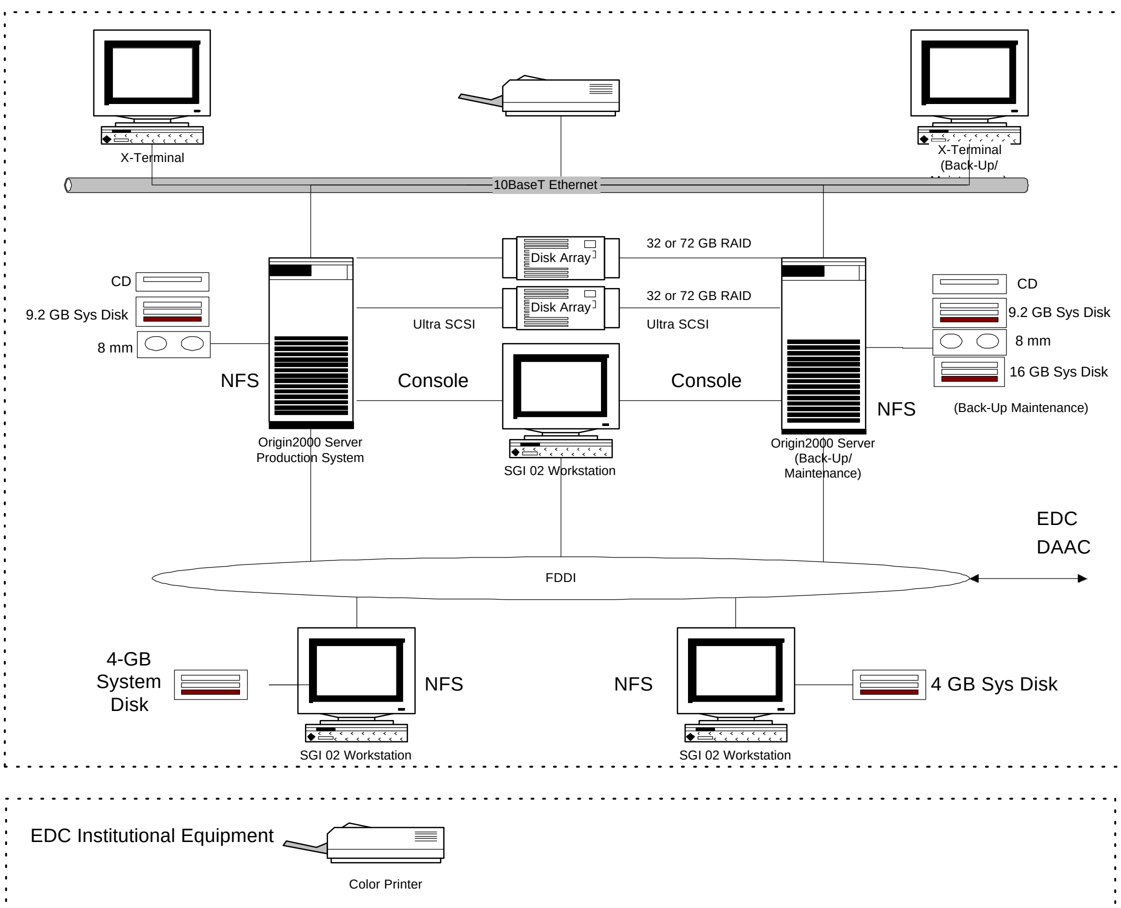

Figure 4–1. LPGS Hardware Configuration

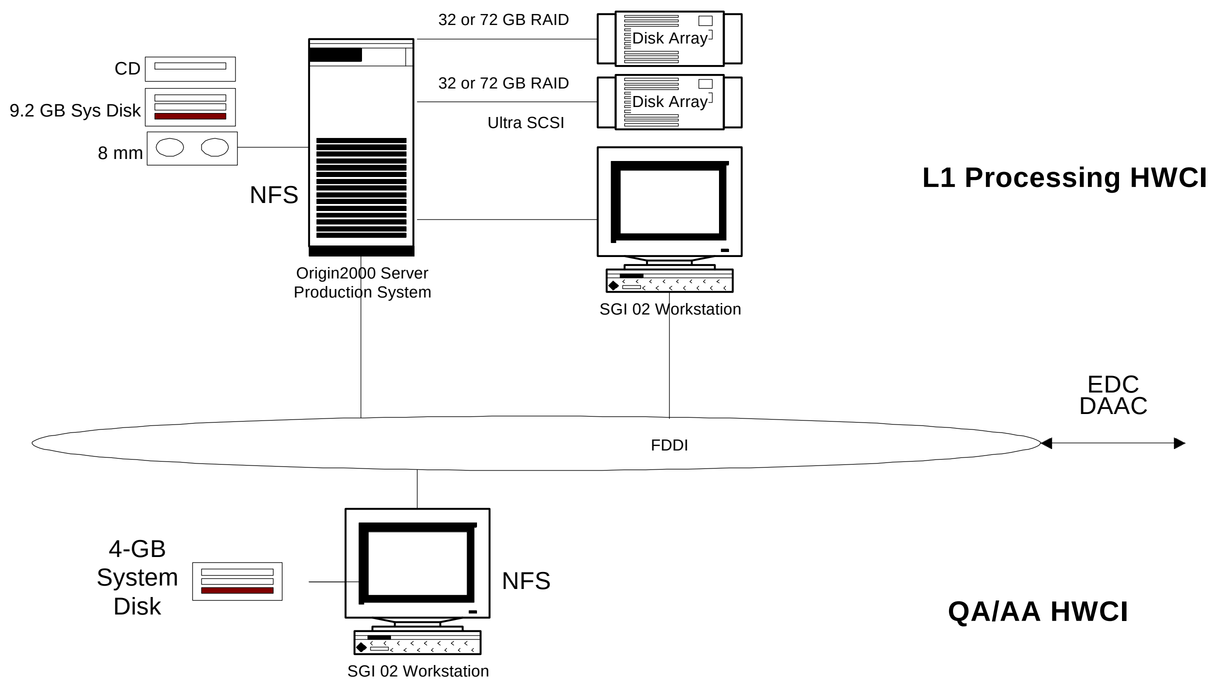

Figure 4–2. Modeled LPGS Hardware Configuration

4.2 Process Flow

The process flow for processing L1 products from ingest to delivery is shown in Figure 4–3.

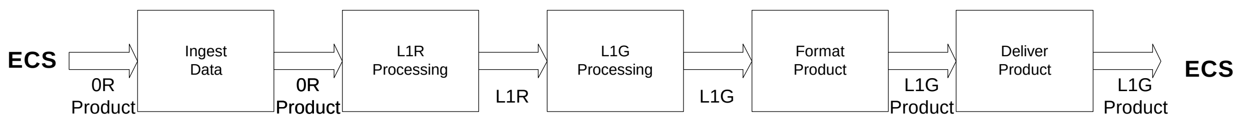

Figure 4–3. LPGS Process Flow

The major functions for each process are described below:

- Ingest data
  - Push 0R (Level 0 data) product to the ingest directory of the LPGS by ECS
  - Move 0R product from the ingest directory to the input directory
  - Verify 0R data quality
- Level 1 radiometrically corrected (L1R) processing
  - 0R radiometric characterization
  - Pre-1R correction
  - 0Rc radiometric characterization/calibration
  - 1R correction
  - 1R radiometric characterization/correction
  - Quality assurance of L1R product
- Level 1 geometrically corrected (L1G) processing
  - Create extended image
  - Resample
  - Quality assurance of L1G product
- Format product
  - Convert L1 product into appropriate format
  - Package L1 product
  - Move L1 product to the output directory
  - Quality assurance of L1 product
- Deliver Product
  - Retrieve L1 product from the output directory by ECS

The detail process flow diagrams for the L1R processing are shown in Appendix A.

4.3 Mapping of Processes/Functions to HWCI

Two operational scenarios are considered in the model: the nominal processing and the non-nominal processing (anomaly analysis). The nominal processing scenario consists of processing a work order from ingest through delivery following the process flow shown in Figure 4–3. The non-nominal processing consists of processing up to three different work orders: benchmark work order, diagnostic processing work order, and reprocessing work order. For modeling purposes, the processing of reprocessing work orders will be treated the same as the processing of normal work orders.

Table 4–1 shows the mapping between the processes/functions identified in Section 4.2 and the HWCIs identified in Section 4.1 for these two scenarios.

Table 4–1. Mapping of Processes/Functions to HWCIs

Process/Function		Nominal Processing	Non-nominal Processing		
			Benchmark Work Order	Diagnostic Work Order	Reprocessing Work Order
Ingest Data					
	Push 0R product to the ingest directory of the LPGS by ECS	L1 Proc HWCI via FDDI	n/a	n/a	n/a
	Move 0R product from the ingest directory to the input directory	L1 Proc HWCI	n/a	n/a	n/a
	Verify 0R data quality	L1 Proc HWCI	n/a	n/a	n/a
L1R Processing					
	0R radiometric characterization	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Pre-1R correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	0Rc radiometric characterization/ calibration	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	1R correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	1R radiometric characterization/ correction	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Quality assurance of L1R product	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
L1G Processing					
	Create extended image	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Resample	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Quality assurance of L1G product	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
Format Product					
	Convert L1 product into appropriate format	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Package L1 product	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Move L1 product to the output directory	L1 Proc HWCI	L1 Proc HWCI	see note	L1 Proc HWCI
	Quality assurance of the L1 product	L1 Proc HWCI	QA/AA HWCI	QA/AA HWCI	L1 Proc HWCI
Deliver Product					
	Retrieve L1 product from the output directory by ECS.	L1 Proc HWCI via FDDI	n/a	n/a	L1 Proc HWCI via FDDI

Note: For the diagnostic processing work order, processing of data will be done on the L1 Processing HWCI but the results will be displayed and analyzed on the QA/AA HWCI.

4.4 Approaches

To estimate the total service time for the L1 product generation from ingest to delivery, it is necessary to estimate the amount of time it takes to process the data as well as the amount of time it takes to transfer the data through various media, including the fiber-optic data distribution interface (FDDI) and disk. The approaches used for estimates are described below.

4.4.1 Data Process

Wherever the benchmark or prototype results are available, the benchmark results are used to extrapolate the processing time for the related functions. Otherwise, the number of instructions required to perform each function is estimated based on the analysis of the available design or algorithms. The processing time is then obtained by multiplying the instruction count with the processing speed of average instructions.

Some prototype results are available for the geometric processing. Therefore the processing time for the geometric processing is extrapolated from these results.

For the radiometric processing, only results for the memory effect correction are available. Therefore, a detailed analysis of the applicable algorithms is performed to estimate the required instruction count for each function. For each function, the analysis includes reviewing the applicable algorithms or prototype code, estimating the number of loops involved, and estimating the number of operations involved within each loop. The total number of instructions is then calculated for each function. These instruction counts are then grouped by steps corresponding to the steps of the radiometric processing flow shown in Appendix A.

The prototype results for the memory effect correction are then used to sanity-check the assumption for the processing speed.

A sample worksheet used for this analysis is shown in Figure 4–4.

4.4.2 Data Transfer

Data transfer needs are identified for each of the major functions in the process flow. The volumes of the data to be transferred through various media for each of the major functions are estimated. Media such as the FDDI and disk are considered.

4.4.3 Data Storage

Data storage needs are estimated for the disk and memory for both the L1 Processing HWCI and QA/AA HWCI. The storage requirement for the disk is estimated for different stages of data processing such as online storage for 72 hours, storage for reprocessing, storage for ingest, storage for images being processed, storage for 0R waiting for processing, etc. The memory required is estimated for each of the major functions. The overall memory requirement is obtained by taking the maximum memory requirement among all functions.

4.1.2 Correct Memory Effect (new from Dennis Helder)

Parameters & Assumptions	**Bands 1-5 & 7**	**Band 6 (Lo & Hi)**	**Band 8**
No. of Bands requiring ME correction	6	1	1
# of filter intervals	3000	3000	6000
# of filter step widths (steps)	7	7	14

Input

Scene (0R)
IC (0R)
Memory Effect magnitude and time constant for each detector

Output

ME corrected image and IC data

Process:

```
1
1.1    for each band
1.2      for each detector
           (Create a vector of filter coefficients for the given
           detector) (not a function of image)
1.3        for each interval of filter
             compute coefficient
           end for interval
           (Convolution)
           (For loop to determine the output of the first specified number (=# of intervals) of minor
           frames (3000))
1.4        for each interval
             for each step
1.6            for each interval (yes, another loop of intervals) (combination of steps and filter step
               width)
                 Compute sum of data under step (5 integer Ops, 3 FP
                 Ops)
               end for interval
1.6a           Add result to output for this interval (8 integer Ops, 4 FP
               Ops)
             end for step
           end for interval
           (Second loop )
1.7        for each scan
1.8          for each pixel
1.9            for each step
                 Compute new output (10 integer Ops, 8 FP Ops)
               end for step
             end for pixel
           for each scan
         end for detector
       end for band
```

Figure 4–4. Sample Worksheet for Instruction Count Estimate (1 of 2)

	Basis	Frequency	Band 1-5&7 No. of Occurrences	Band 6 No. of Occurrences	No. of Occurrences	No. of Integer Ops	No. of FP Ops	Total Integer Ops (Mega)	Total FP Ops (Mega)
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.3	by interval	1	3000	3000	6000				
	overall	1	288000	24000	192000	2	100	1.008	50.400
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.4	by filter interval	1	3000	3000	6000				
1.6 (except 1.6a)	by filter interval	1	3000	3000	6000				
	overall	1	864000000	72000000	1152000000	7	3	14616.000	6263.994
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.4	by filter interval	1	3000	3000	6000				
1.5, 1.6a	by step	1	7	7	14				
	overall	1	2016000	168000	2688000	10	4	48.720	19.488
Scene Data									
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.7	by scan	1	374	374	374				
1.8	by pixel	1	6600	3300	13200				
1.9	by step	1	7	7	14				
	overall	1	1658764800	69115200	2211686400	12	8	47274.797	31516.500
IC Data									
1.1	by band	1	6	1	1				
1.2	by detector	1	16	8	32				
1.7	by scan	1	374	374	374				
1.8	by pixel	1	1160	580	2320				
1.9	by step	1	7	7	14				
	overall	1	291540480	12147520	388720640	12	8	8308.904	5539.264
Misc.	by band	1	6	1	1		10000	0.000	0.080
Total								70249.428	43389.725

Figure 4–4. Sample Worksheet for Instruction Count Estimate (2 of 2)

4.5 Parameters and Assumptions

This section describes the parameters and assumptions used globally in the model. These include parameters used for file size estimate, image size estimate, and hardware characteristics.

4.5.1 Image-Related Parameters

Table 4–2 summarizes the parameters/values pertaining to the images. Some of these parameters are also used for the estimation of loop counts in the instruction count estimation. Parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. The sources of data are shown in the Note column.

Table 4–2. Parameters for Image Size

	Scene Size =		**1**	**WRS Scene(s)**				
Scene size	***1***							
Major Frame Period (ETM+ Scan Time)	***71.343*** ms							
Number of Scans/WRS Scene	***374*** scans							
	Unit	**Bands 1-5 & 7**	**Band 6 (Lo & Hi)**	**Band 8**	**Format 1/2**	**Product**	**Complete Scene**	**Note**
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
0R Scene Data								
Pixels/Scan Line	Pixel	***6600***	***3300***	***13200***				Landsat 7 0R DFCB (sec. 4.0)
Scan Lines/Scan		***16***	***8***	***32***				Landsat 7 0R DFCB (sec. 4.0)
Number of Scans/Band/Scene		***374***	***374***	***374***				Landsat 7 0R DFCB (sec. 3.1)
Pixels/Band/Scene	Pixel	39494400	9873600	157977600				
Pixels/Band/Scene	Mega Pixel	39.50	9.88	157.98				
Pixels/Scene	Pixel	236966400	9873600	157977600				
Pixels/Scene	Mega Pixel	236.97	9.88	157.98			**404.83**	
L1G Scene Data								
Scene Width	km	***170***	***170***	***170***				
Scene Length	km	220	220	220				
Resampled Size	km/pixel	0.0250	0.0250	0.0125				
Pixels/Band/Scene	Pixel	59840000	59840000	239360000				
Pixels/Band/Scene	Mega Pixel	59.84	59.84	239.36				
Pixels/Scene	Pixel	359040000	59840000	239360000				
Pixels/Scene	Mega Pixel	359.04	59.84	239.36			**658.24**	
Internal Calibration Data								
Pixel/Scan Line	Pixel	***1160***	***580***	***2320***				Landsat 7 0R DFCB (Table 5.1)
Scan Lines/Scan		***16***	***8***	***32***				Landsat 7 0R DFCB (sec. 4.0)
Number of Scans/Band/Scene		***374***	***374***	***374***				Landsat 7 0R DFCB (sec. 3.1)
Pixels/Band/Scene	Pixel	6941440	1735360	27765760				
Pixels/Band/Scene	Mega Pixel	6.95	1.74	27.77				
Pixels/Scene	Pixel	41648640	1735360	27765760				
Pixels/Scene	Mega Pixel	41.65	1.74	27.77			**71.16**	

4.5.2 MSCD, PCD, CPF, Metadata, Geometric Grid, and LPGS-Generated Data

Table 4–3 summarizes the parameters/values used to estimate the file size for MSCD, PCD, CPF, metadata, geometric grid, and LPGS-generated process-related file. Parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. The sources of data are shown in the Note column.

Table 4–3. Parameters for File Size Estimates for MSCD, PCD, Metadata, CPF, Geometric Grid, and LPGS-Generated File (1 of 2)

	Scene Size =		**1**	**WRS Scene(s)**				
Scene size	***1***							
Major Frame Period (ETM+ Scan Time)	***71.343***	ms						
Number of Scans/WRS Scene	***374***	scans						
	Unit	**Bands 1-5 & 7**	**Band 6 (Lo & Hi)**	**Band 8**	**Format 1/2**	**Product**	**Complete Scene**	**Note**
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
MSCD Data								
Bytes/Record	Byte				***79***			Landsat 7 0R DFCB (Table 5.2)
Number of Records/Scan					***1***			Landsat 7 0R DFCB (Table 5.2)
Number of Scans/Format/Scene					***374***			Landsat 7 0R DFCB (sec. 3.1)
Bytes/Format/Scene	Byte				29546			
Bytes/Scene	Byte				59092			
Bytes/Scene	Megabyte				0.06		0.06	
PCD Data								
Bytes/Record	Byte				***26472***			Landsat 7 0R DFCB (Table 5.3)
Number of records for 14 min interval/Format					***206***			Landsat 7 0R DFCB (Table 5.3)
Bytes/14 min./Format	Byte				5453232			Assume worst case of 14 min w/o subsetting
Bytes/14 min.	Byte				10906464			
Bytes/14 min.	Megabyte				10.91		10.91	
LPS Meta Data (ASCII Text)								
Bytes/Record	Byte				***80***			Assume one text line per record
Number of Records for Header					***60***			Landsat 7 0R DFCB (Table 5.4)
Number of Records/ Scene/Format					***91***			Landsat 7 0R DFCB (Table 5.4)
Number of Scenes/Format					***2***			Assume not starting at WRS scene boundary
Number of Record/Format					***242***			
Factor to include comments					***2***			Assumption
Bytes/Format/Scene	Byte				38720			
Bytes/Scene	Byte				77440			
Bytes/Scene	Megabyte				0.08		0.08	
ECS Meta Data (ASCII Text)								
Bytes/Record	Byte					***80***		Assume one text line per record
Number of Records/Product						***49***		Landsat 7 0R DFCB (Table 5.5)
Factor to include comments						***2***		Assumption
Bytes/Scene	Byte					7840		
Bytes/Scene	Megabyte					0.01	0.01	

Table 4–3. Parameters for File Size Estimates for MSCD, PCD, Metadata, CPF, Geometric Grid, and LPGS-Generated File (2 of 2)

	Unit	Bands 1-5 & 7	Band 6 (Lo & Hi)	Band 8	Format 1/2	Product	Complete Scene	Note
	Scene Size =		**1**	**WRS Scene(s)**				
Scene size	***1***							
Major Frame Period (ETM+ Scan Time)	***71.343***	ms						
Number of Scans/WRS Scene	***374***	scans						
Total Number of Bands/Formats		***6***	***1***	***1***	***2***			
Calibration Parameter File (ASCII Text)								
Bytes/Record	Byte					***80***		Assume one text line per record
Number of Records/Product						***1243***		Landsat 7 CPF Definition, assume 11 records per page, 113 pages
Factor To Include Comments						***2***		Assumption
Bytes/Scene	Byte					198880		
Bytes/Scene	Megabyte					0.20	0.20	
Total for MSCD/PCD/Meta Data/CPF							**11.06**	
LPGS Process Data (accounting, status, characterization results etc.)								
Bytes/Band/1 WRS scene	Megabytes	***1.5***	***1.5***	***4***				Assumption
Bytes/Band/Scene	Megabytes	1.5	1.5	4				
Bytes/Scene	Megabytes	9	1.5	4				
Total for LPGS Process Data (accounting, status, characterization results etc.)							**14.50**	
Geometric Grid								
Bytes/Band	Megabytes	***4***	***2***	***8***				Assumption
Bytes/Total (scene independent)	Megabytes	24	2	8				
Total for Geometric Grid							**34.00**	

4.5.3 System-Level Parameters

Additional parameters used are summarized in Table 4–4. Parameters are shown in ***Bold Italic*** and the derived values are shown in regular font. These parameters are used at the system level and are further discussed below.

- Error margins

  These values account for the estimation inaccuracies and are expressed in percentages.

- Operating system and program overheads

  These values account for the additional space needed for the operating system and programs.

- Additional requirements per functional and performance requirements specification (F&PRS)

  As imposed by the LPGS performance requirements 4.1.4 and 4.1.5, the LPGS shall provide at least 125 percent of storage and memory capacity required to satisfy the worst-case loading. These values are used to account for these requirements and are expressed in percentages.

Table 4–4. System-Level Parameters

Error Margin	
Processing	***50%***
Benchmark	***0%***
Memory	***5%***
Disk I/O	***10%***
FDDI I/O	***10%***
Disk Storage	***5%***
O/S & Program O/H	
Processing	***0***
Benchmark	***0***
Memory	***115*** MB [40 M for UNIX O/S, 50 M for swap, 15 M for Oracle, 10 m for program (76.5 K DSI for LPGS + 50 K for COTS @ 80 B/DSI)]
Disk I/O	0
FDDI I/O	0
Disk Storage	0 GB (Assuming system disk not in RAID)
Additional Requirement per F&PRS	
Processing	***0%***
Benchmark	***0%***
Total Processing Time	***0%***
Memory	***25%***
Disk I/O	***0%***
FDDI I/O	***0%***
Disk Storage	***25%***
Number of Bands	
Bands 1-5 & 7	6
Band 6 (Lo & Hi)	1
Band 8	1
Benchmark Results	
Bands 1-5 & 7	***167.407*** seconds
Band 6 (Lo & Hi)	***125.553*** seconds
Band 8	***669.60*** seconds
CPU Processing Time	
Origin 2000 CPU speed	***195*** MHz
# of cycles/average instruction	***2.0*** cycles/instruction
Origin 2000 Processing Time	0.01026 micro seconds/ops
W/S O2 CPU speed	***150*** MHz
FDDI transfer rate	***60*** Mbps
RAID transfer rate	***70*** MBPS
W/S Disk transfer rate	***20***MBPS
CPU overhead during FDDI data transfer	***20%***
Origin 2000 CPU O/H associated with FDDI data transfer	0.0267sec/MB
W/S O2 CPU O/H associated with FDDI data transfer	0.0267 sec/MB
Number of CPU cycles for transferring 1 byte of data	***2*** cycles/byte (Assuming it takes 2 cycles of CPU to transfer 1 byte of data)
Origin 2000 CPU O/H associated with disk data transfer	0.01026 sec/MB
W/S O2 CPU O/H associated with disk data transfer	0.01333 sec/MB
Origin 2000 CPU degradation factor for multiple CPUs	***7%***

- Hardware-related parameters
  - Central processing unit (CPU) speed

    The CPU of the Origin 2000 system is a 195-MHz processor while the CPU of the O2 workstation is a 150-MHz processor.

  - Number of CPU cycles for average instruction

    The Origin 2000 is rated as a 390-Million Floating Point Operations (MFLOPS) (peak, or 0.5 cycles per instruction) processor since it can execute two floating point operations in one CPU cycle. This is because an instruction called "multiply-add" which consists of two operations—multiplication and addition—can be executed in one CPU cycle. However, most of the instructions take one or more cycles. Instructions such as floating point addition, subtraction, and multiplication take one cycle and floating point division takes 14 cycles. The 390 MFLOPS is the theoretical best performance of the Origin 2000. The real performance depends on the application and the way the software is implemented. The Linpack benchmark result for a single CPU is 344 MFLOPS.

    Benchmark results that are obtained from the Netlib Repository Database (http://performance.netlib.org/) show that the Origin 200 can achieve 80 to 270 MFLOPS depending on the instruction mix (see Table 4–5). The Origin 200 also uses the same MIPS R10000 processors as Origin 2000 but is slightly slower (180 MHz). It can be extrapolated that the Origin 2000 can achieve 90 to 300 MFLOPS with the same instruction mix. The radiometric algorithms include a significant number of divisions, square root operations, which require many cycles to execute. Therefore the instruction mix might be closer to the instruction mix used in Benchmark 1 or 2 of Table 4–5.

Table 4–5. Benchmark Results for Origin 200

	Floating Point Addition	Floating Point Subtraction	Floating Point Multiplication	Floating Point Division	Origin 200 MFLOPS
Benchmark 1	40.4%	23.1%	26.9%	9.6%	84.346
Benchmark 2	38.2%	9.2%	43.4%	9.2%	79.996
Benchmark 3	42.9%	3.0%	50.7%	3.4%	154.366
Benchmark 4	42.9%	2.2%	54.9%	0.0%	269.263

The Silicon Graphics, Inc. (SGI) engineer has indicated that a program not properly implemented for parallel processing can be improved from 40 MFLOPS initially to about 100 MFLOPS after performance tuning and proper adjustment. Therefore two cycles per average instruction is used in computing the processing time required for the radiometric processing in this analysis. This is equivalent to 97.5 MFLOPS. This optimistic estimate may not be achieved at the initial implementation. (However, based on the Linpack benchmark results, 97.5 MFLOPS may be too conservative.)

The benchmark results obtained from the memory effect correction prototype are used as another data point for choosing two cycles per average instruction. The scientist has indicated that the processing time for the memory effect correction is about 2 minutes for a single band of Bands 1–5 using DEC Alpha 600 5/266. (The speed of the Origin 2000 is about 20 to 60 percent faster than DEC Alpha 600 based on the SPECint95 and SPECfp95.) This is equivalent to a processing time of 28 minutes to correct the memory effect for all bands. If two cycles per instructions is used, the processing time for the memory effect correction for all bands based on the instruction count estimate is about 29 minutes. This number is very close to the processing time extrapolated from the benchmark results.

Two cycles per instruction is equivalent to 0.01025 microseconds per instruction.

– FDDI transfer rate

  The FDDI transfer rate is assumed to be 60 megabits per second.

– Aggregate disk transfer rate

  The aggregate disk transfer rate [redundant arrays of independent disks (RAID), small computer system interface (SCSI)] is assumed to be 70 megabytes per second (MBPS) with two SCSI III interfaces concatenated.

– Workstation disk transfer rate

  The disk transfer rate for the O2 workstation is assumed to be 20 MBPS.

– CPU overhead during FDDI data transfer

  It is assumed that 20 percent of one CPU time will be required during FDDI data transfer.

– Number of CPU cycles for transferring 1 byte of data

  It is assumed that two CPU cycles will be required to transfer 1 byte of data to or from the disk.

4.6 Benchmark Results

Preliminary benchmark results for the Image Assessment System (IAS) executed on an SGI Origin 2000 provided the basis for the LPGS geometric CPU loads. The data are summarized in Table 4–6.

The processing time for each of Bands 1 through 5 and Band 7 is about 180 seconds total with four CPUs. In this study, the CPU processing time is estimated based on one CPU, and a degradation factor is applied to derive the processing time for multiple CPUs. With a four-CPU configuration, the degradation factor to be used is 7 percent. This leads to an estimate of 167.40 seconds for Bands 1 through 5 and Band 7 with one CPU. Band 6 requires 75 percent of the amount of processing, or 125.55 seconds. Band 8 requires four times the amount of processing, or 669.60 seconds.

Table 4–6. Benchmark Results for Geometric Processing

Number of CPUs	CPU Time (sec)
1	143
2	78
3	57
4	45
5	37
6	33
7	29
8	27

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5. Model Results

5.1 Model Implementation

Two performance models were developed: a Microsoft Excel spreadsheet model and a discrete-event/analytical model using Quantitative Case for Reliability and Timing (QASE RT). This section describes the spreadsheet model and discusses the results obtained from the spreadsheet model. The discrete event model using QASE is discussed in the Appendix B.

5.2 Description of Microsoft Excel Spreadsheet Model

A Microsoft Excel spreadsheet model was developed to estimate the instruction counts, processing time, data volume, data transfer time, and data storage. The model consists of three spreadsheet files: “PROCESS,” “DATA,” and “SUM.”

The PROCESS spreadsheet file details high-level processes for each function in the radiometric processing, the number of loops involved, and the number of instructions for each loop. The total instruction count for each function is then calculated. This spreadsheet generates the raw data for the SUM file and QASE model.

The DATA spreadsheet file details the amount of data transfer and amount of data storage required at each step of the process flow. This spreadsheet consists of several sections such as FDDI, disk input/output (I/O), memory, and disk storage. This spreadsheet generates the raw data for the SUM file and QASE model.

The SUM spreadsheet file is linked to the PROCESS and DATA files and uses the raw data generated from PROCESS and DATA files for summarization. Error margins, operating system overheads, and additional reserves are added to the raw data in this spreadsheet.

5.3 Spreadsheet Model Results

5.3.1 Spreadsheet Model Results—Without Error Margins and Overheads

The data presented below are considered as the raw data. These data are estimated using spreadsheet files PROCESS and DATA. These data do not include error margins, operating system overheads, and additional reserves required by the F&PRS. These raw data are used for the spreadsheet SUM as well as the QASE model and include the following:

- Level 1 Processing HWCI
  - Number of instructions estimated for each major step of the radiometric processing (from PROCESS)
  - Processing time estimated from benchmark results for the geometric processing (treated as parameters)
  - Memory storage estimated for each major step of the LPGS process flow (from DATA)

- Amount of data transfer estimated for the disk I/O (from DATA)
- Mount of data transfer estimated for the FDDI (from DATA)
- Disk storage (from DATA)

- QA/AA HWCI
  - Memory storage estimated (from DATA)
  - Amount of data transfer estimated for the disk I/O (from DATA)
  - Amount of data transfer estimated for the FDDI (from DATA)
  - Disk storage (from DATA)

5.3.1.1 Data Process

The number of instructions is estimated using the spreadsheet file PROCESS. The estimated instruction counts for all functions in the radiometric processing for one WRS scene are summarized in Table 5–1. Parameters used locally by each function are also indicated. The results indicate that 62.45 percent and 15.48 percent of the radiometric processing are for the memory effect correction and banding correction, respectively. The remaining functions contribute a total of 22.07 percent of the total instruction count of the radiometric processing.

5.3.1.2 Data Transfer

The data volumes transferred are estimated using the spreadsheet file DATA. The estimated data volumes transferred for one WRS scene through the FDDI are shown in Table 5–2. The estimated data volumes transferred for one WRS scene through the disk are shown in Table 5–3 for the nominal processing and in Table 5–4 for the non-nominal processing.

For the non-nominal processing, the data volumes transferred are estimated assuming that all bands for all image files including intermediate files are to be read for assessment by the analyst. In reality, the analyst may only be interested in certain bands or certain files. The actual amount of data to be transferred could be significantly less.

5.3.1.3 Data Storage

The amount of data storage required is estimated using the spreadsheet file DATA. The memory estimates by data type and by band for the nominal processing are summarized in Table 5–5. The memory estimates assume that the entire band of one WRS scene will be read into the memory for processing. The newly improved geometric processing allows processing on smaller amounts of data within a band (e.g., 150 scans of data). Therefore, the memory requirements for geometric processing could be proportionally reduced (e.g., memory for 150 scans of data only). However, the radiometric processing still requires the entire band to be memory resident. Commercial off-the-shelf (COTS) software packages such as the Environment for Visualizing Images (ENVI), Interactive Data Language (IDL), Oracle, and FrameMaker will be used as the tools for visual quality assessment for the workstations of the QA/AA HWCI. Therefore, the memory requirements are driven by these software packages. It is estimated that 128 MB total memory will be required for the workstation.

Table 5–1. Instruction Count Summary for Radiometric Processing for One WRS Scene (1 of 2)

Process Specific Parameters/Ops		Freq of Proc	Bands 1–5 and 7	Band 6 (Low and High)	Band 8	Total Int Ops (Mega)	Total FP Ops (Mega)	Total Ops (Mega) (X frequency)	% with respect to Total
2.1 Characterize Impulse Noise		1				441.129	853.876	1295.005	0.71%
% of pixels with impulse noise	0.01								
2.3 Locate Scan-Correlated Shift (SCS)		1				4574.991	2.474	4577.465	2.52%
% of scan lines with SCS state transition	0.3								
# of detectors used to determine SCS levels			3	3	3				
2.5 Characterize Dropped Lines		1				857.657	0.080	857.737	0.47%
% of scan lines with filled data	0.3								
# of dropped lines/scan line	2								
# of dropped lines for scene			21542.4	1795.2	7180.8				
# of dropped lines for IC			21542.4	1795.2	7180.8				
2.6a Characterize Detector Saturation (A/D)		1				2927.199	0.080	2927.279	1.61%
% of A/D saturated pixel	0.01								
2.6b Characterize Detector Saturation (Analog)		1				961.454	1965.823	2927.277	1.61%
% of analog saturated pixel	0.01								
2.10a Histogram Analysis (Integer Operations)		1				3242.023	0.284	3242.307	1.78%
% of detectors w/o impulse noise and dropped lines	1								
# of bins per detector			256	256	256				
2.10b Histogram Analysis (Floating Point Operations)		2				810.451	2469.987	6560.877	3.61%
% of detectors w/o impulse noise and dropped lines	1								
# of bins per detector			3000	3000	3000				
3.4.1 Process IC Data - Emissive Band		1				640.653	2318.120	2958.773	1.63%
% of pixels in IC associated with dark current region	0.5								
# of pixels in the dark current area			580	290	1160				
% of pixels in IC associated with shutter data	0.5								
# of pixels in the shutter area			580	290	1160				
3.4.2 Process IC Data - Reflective Band		1				313.535	2282.183	2595.719	1.43%
% of pixels in IC associated with shutter data	0.5								
% scan with scans with ghost pulse	0.3								
# of pixels in the shutter area			580	290	1160				
# of lamp state per detector			2	2	2				
# of bands used for lamp state determination			2	2	2				

Table 5–1. Instruction Count Summary for Radiometric Processing for One WRS Scene (2 of 2)

Process Specific Parameters/Ops		Freq of Proc	Bands 1–5 and 7	Band 6 (Low and High)	Band 8	Total Int Ops (Mega)	Total FP Ops (Mega)	Total Ops (Mega) (X frequency)	% with respect to Total
4.1.1 Combine Image and IC		1				1903.869	0.040	1903.909	1.05%
% of line in forward scan	0.5								
% of line in reverse scan	0.5								
4.1.2 Correct Memory Effect (new from Dennis Helder)		1				70249.428	43389.725	113639.153	62.45 %
No. of Bands requiring memory effect correction			6	1	1				
# of filter intervals			3000	3000	6000				
# of filter step widths (steps)			7	7	14				
4.1.3 Apply Scan-Correlated Shift (SCS)		1				952.036	762.644	1714.681	0.94%
% of lines need SCS correction	0.3								
% of lines do not need SCS correction	0.7								
4.1.4 Apply Coherent Noise Correction		1				951.935	1428.021	2379.955	1.31%
% of scan lines with filled data	0.3								
4.1.6 Separate Image and IC		1				951.935	951.974	1903.908	1.05%
% of line in forward scan	0.5								
% of line in reverse scan	0.5								
4.2 Apply Radiometric Correction		1				809.635	2024.166	2833.801	1.56%
4.3.1 Correct Dropped Lines		1				145.795	516.253	662.049	0.36%
% of scan lines with filled data	0.3								
# of dropped lines/scan line	2								
# of dropped lines for scene			3590.4	1795.2	7180.8				
% of pixels with filled data/line	0.6								
# of pixels/dropped line			1980	990	3960				
Dropped line correction method (Fill, Inline, Interpolate)	Interpolate								
4.3.2 Correct Inoperable Detectors		1				0.086	0.351	0.437	0.00%
# of inoperable detectors			2	1	2				
Inoperable detector correction method (Fill, Interpolate)	Interpolate								
4.3.4 Correct Stripping		1				809.635	0.216	809.851	0.45%
4.3.5 Correct Banding		1				7529.607	20645.757	28175.364	15.48%
% of scan lines with banding	0.3								
6.5 Gain Switch and Apply Relative Gain Correction		1				0.000	0.107	0.107	0.00%
TOTAL						99073.055	79612.162	181965.656	100.00 %
Total (excluding memory effect correction)						28823.627	36222.437	68326.502	
Total (excluding memory effect and banding)						21294.019	15576.680	40151.138	

Table 5–2. Volume of Data Transferred via FDDI for One WRS Scene (Raw Data)

FDDI Data Transfer for 1 WRS Scene for Nominal Processing

	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Bytes/ pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
Ingest Data										
Write 0R Data to disk	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Write IC Data (0R) to disk	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Write MSCD/PCD/Meta/CPF to disk	byte								11.06	11.06
Total for Ingestion						**46.5**	**11.6**	**185.8**	**11.1**	**487.1**
Deliver Product										
Read L1G Data from Disk	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read IC Data (L1G) from disk	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read LPGS Process related data from disk	byte					1.50	1.50	4.00		14.50
Read MSCD/PCD/Meta/CPF from disk	byte								11.06	11.06
Total for Deliver Product						**135.1**	**124.7**	**538.3**	**11.1**	**1484.5**
Grand Total						**181.5**	**136.3**	**724.0**	**22.1**	**1971.6**

FDDI Data Transfer for 1 WRS Scene for Anomaly Analysis

	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Bytes/ pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
AAS										
Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read IC Data (L1R) into memory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read L1G Data into memory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for AAS						**633.6**	**250.5**	**2530.0**	**11.1**	**6593.31**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing for One WRS Scene (Raw Data) (1 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing											
		Type	**Bands 1-5 & 7 (M Pixels)**	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/ Pixel**	**Bands 1-5 & 7 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**	**Band Independen t (M Bytes)**	**Total for 1 WRS Scene (M Bytes)**
Ingest Data											
	Write 0R Data to disk	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Write IC Data (0R) to disk	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Write MSCD/PCD/Meta/CPF to disk	byte								11.06	11.06
	Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write 0R Data to input directory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Write IC Data (0R) to input directory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Write MSCD/PCD/Meta/CPF to input directory	byte								11.06	11.06
Total for Ingestion							**139.4**	**34.9**	**557.3**	**33.2**	**1461.4**
Level 1R Process											
Process # 1											
Step 1	0R Radiometric Characterization										
	Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
	Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Total for Step 1						**46.5**	**11.6**	**185.8**	**11.1**	**487.1**
Step 2	Pre-1R Correction										
	Write 0Rc Data to disk	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Write IC Data (0Rc) to disk	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 2						**187.3**	**48.0**	**747.0**	**0.0**	**1918.8**
Process # 2											
Step 3	0Rc Radiometric Characterization/Calibration										
	Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 3						**187.3**	**48.0**	**747.0**	**11.1**	**1929.8**
Step 4	1R Correction										
	Write 1R Data to disk	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Write IC Data (1R) to disk	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Write LPGS Process data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 4						**187.3**	**48.0**	**747.0**	**0.0**	**1918.8**
Process # 3											
Step 5	1R Radiometric Characterization/Correction										
	Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
	Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
	Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
	Write L1R Data to disk	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
	Write IC Data (L1R) to disk	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
	Write LPGS Process data to disk	byte					1.50	1.50	4.00		14.50
	Total for Step 5						**280.2**	**71.2**	**1118.5**	**11.1**	**2882.0**
Total for 1R Processing							**888.6**	**226.8**	**3545.3**	**33.2**	**9136.5**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing for One WRS Scene (Raw Data) (2 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing										
	Type	**Bands 1-5 & 7 (M Pixels)**	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/ Pixel**	**Bands 1-5 & 7 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**	**Band Independent (M Bytes)**	**Total for 1 WRS Scene (M Bytes)**
QA for L1R										
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for L1R QA						**82.0**	**22.8**	**324.0**	**11.1**	**849.8**
Level 1G Process										
Step 1 Create Extended Image										
Read 1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write Extended Image to disk**	16 bit int.	39.50	9.88	157.98	2.5	98.75	24.70	394.95		1012.15
(** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)										
Write Geometric Grid to disk	byte					4.00	2.00	8.00		34.00
Total for Step 1						**181.8**	**46.5**	**718.9**	**11.1**	**1866.9**
Step 2 Resample										
Read Extended image into memory**	16 bit int.	39.50	9.88	157.98	2.5	98.75	24.70	394.95		1012.15
(** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)										
Read Geometric Grid into memory	byte					4.00	2.00	8.00		34.00
Write L1G Data to disk	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for Step 2						**223.9**	**147.9**	**885.7**	**0.0**	**2377.1**
Total for 1G Processing						**405.7**	**194.3**	**1604.6**	**11.1**	**4244.1**
QA for L1G										
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read L1G Data into memory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for L1G QA						**122.7**	**122.7**	**486.7**	**11.1**	**1356.5**
Format Product										
Read L1G Data into memory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read IC Data (L1R) into memory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write L1G Data to output directory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Write IC Data (L1R) to output directory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Write LPGS Process related data to output directory	byte					1.50	1.50	4.00		14.50
Write MSCD/PCD/Meta/CPF to output directory	byte								11.06	11.06
Total for Format Product						**270.2**	**249.3**	**1076.5**	**22.1**	**2968.9**

Table 5–3. Data Volume Transferred via Disk for Nominal Processing for One WRS Scene (Raw Data) (3 of 3)

Disk I/O for 1 WRS Scene for Nominal Processing	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Byte/ Pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent (M Bytes)	Total for 1 WRS Scene (M Bytes)
Final QA										
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read L1G Data into memory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for Final QA						**122.7**	**122.7**	**486.7**	**11.1**	**1356.5**
Deliver Product										
Read L1G Data from Disk	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read IC Data (L1G) from disk	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read LPGS Process related data from disk	byte					1.50	1.50	4.00		14.50
Read MSCD/PCD/Meta/CPF from disk	byte								11.06	11.06
Total for Deliver Product						**135.1**	**124.7**	**538.3**	**11.1**	**1484.5**
Grand Total						**2166.2**	**1098.1**	**8619.3**	**143.8**	**22858.2**

Table 5–4. Data Volume Transferred via Disk for Non-nominal Processing for One WRS Scene (Raw Data)

Disk I/O for 1 WRS Scene for Anomaly Analysis	Type	Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Bytes/pixel	Bands 1-5 & 7 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)	Band Independent	Total for 1 WRS Scene (M Bytes)
AAS										
Read 0R Data into memory	byte	39.50	9.88	157.98	1	39.50	9.88	157.98		404.86
Read IC Data (0R) into memory	byte	6.95	1.74	27.77	1	6.95	1.74	27.77		71.21
Read LPGS Process related data into memory	byte					1.50	1.50	4.00		14.50
Read 0Rc Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (0Rc) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read 1R Data into memory	FP	39.50	9.88	157.98	4	158.00	39.52	631.92		1619.44
Read IC Data (1R) into memory	FP	6.95	1.74	27.77	4	27.80	6.96	111.08		284.84
Read L1R Data into memory	16 bit int.	39.50	9.88	157.98	2	79.00	19.76	315.96		809.72
Read IC Data (L1R) into memory	16 bit int.	6.95	1.74	27.77	2	13.90	3.48	55.54		142.42
Read L1G Data into memory	16 bit int.	59.84	59.84	239.36	2	119.68	119.68	478.72		1316.48
Read MSCD/PCD/Meta/CPF into memory	byte								11.06	11.06
Write LPGS Process related data to disk	byte					1.50	1.50	4.00		14.50
Total for AAS						**633.6**	**250.5**	**2530.0**	**11.1**	**6593.31**
Note: The same amount of data needs to be written to the disk of the AA/QA HWCI										

Table 5–5. Memory Requirements per Band for One WRS Scene for Nominal Processing (Raw Data)(1 of 2)

Memory Requirements per Band per WRS Scene for Nominal Processing		Bands 1-5 & 7 (M Pixels)	Band 6 (Lo & Hi) (M Pixels)	Band 8 (M Pixels)	Byte/Pixel	Bands 1-5 & 8 (M Bytes)	Band 6 (Lo & Hi) (M Bytes)	Band 8 (M Bytes)
Ingest Data								
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Ingest data					57.51	22.68	196.81
Ingest Data Memory Requirements						**57.51**	**22.68**	**196.81**
L1R Processing								
Step 1	0R Radiometric Characterization							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 1					57.51	22.68	196.81
Step 2	Pre-1R Correction							
	0R Image	39.50	9.88	157.98	1	39.50	9.88	157.98
	IC for 0R	6.95	1.74	27.77	1	6.95	1.74	27.77
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 2					244.81	70.66	943.81
Step 3	0Rc Radiometric Characterization							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 3					198.36	59.04	758.06
Step 4	1R Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 4					198.36	59.04	758.06
Step 5	1R Radiometric Characterization/Correction							
	1R Image	39.50	9.88	157.98	4	158.00	39.52	631.92
	IC for 1R	6.95	1.74	27.77	4	27.80	6.96	111.08
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for Step 5					198.36	59.04	758.06
	(* Assume L1R image will be written to disk scan by scan)							
QA for L1R								
	L1R Image	39.50	9.88	157.98	2	79.00	19.76	315.96
	LPGS Process Related Data					1.50	1.50	4.00
	MSCD/PCD/Meta/CPF					11.06	11.06	11.06
	Total for L1R QA					91.56	32.32	331.02
L1R Processing Memory Requirements*						**244.81**	**70.66**	**943.81**
	(* Maximum of steps 1-5 and L1R QA)							

Table 5–5. Memory Requirements per Band for One WRS Scene for Nominal Processing (Raw Data) (2 of 2)

Memory Requirements per Band per WRS Scene for Nominal Processing									
			Bands 1-5 & 7 (M Pixels)	**Band 6 (Lo & Hi) (M Pixels)**	**Band 8 (M Pixels)**	**Byte/Pixel**	**Bands 1-5 & 8 (M Bytes)**	**Band 6 (Lo & Hi) (M Bytes)**	**Band 8 (M Bytes)**
L1G Processing									
Step 1 &2	Create Extended Image/Resample								
	L1R Image		39.50	9.88	157.98	4	158.00	39.52	631.92
	L1R Extended Image	1.25	49.38	12.35	197.48	4	197.50	49.40	789.90
	L1G Output Image		59.84	59.84	239.36	2	119.68	119.68	478.72
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Geometric Grid						4.00	2.00	8.00
	Total for Steps 1 & 2*						214.06	134.24	812.96
	(*Assuming L1R image not to be retained)								
	(*Assuming L1G will be output as it is generated)								
QA for L1G									
	L1G Image		59.84	59.84	239.36	2	119.68	119.68	478.72
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for L1G QA						132.24	132.24	493.78
L1G Processing Memory Requirements*							**214.06**	**134.24**	**812.96**
	(* Maximum of Steps 1&2 and L1G QA)								
Format Product									
Format Product									
	L1G Image		59.84	59.84	239.36	2	119.68	119.68	478.72
	IC Data (L1G)		6.95	1.74	27.77	2	13.90	3.48	55.54
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for Format Product						**146.14**	**135.72**	**549.32**
Final QA									
	L1G Image		59.84	59.84	239.36	2	119.68	119.68	478.72
	LPGS Process Related Data						1.50	1.50	4.00
	MSCD/PCD/Meta/CPF						11.06	11.06	11.06
	Total for Final QA						**132.24**	**132.24**	**493.78**
Format Product Memory Requirements*							**146.14**	**135.72**	**549.32**
	(* Maximum of Steps 1-3 & Final QA)								
Deliver Product							**minimal**	**minimal**	**minimal**

The disk storage estimates for the LPGS are summarized in Table 5–6 for the L1 Processing HWCI and in Table 5–7 for the QA/AA HWCI.

Table 5–6. Disk Storage Requirements for L1 Processing HWCI (Raw Data) (1 of 2)

Disk Storage for L1 Processing HWCI							
	Type	Mega Pixels	Bytes/Pixel	Total Mega Bytes per item	Frequency/ Occurrence	Total Mega Bytes	**Total Giga Byte**
Online Storage							
# of Scene per day					25		
# of days					3		
L1G Image		658.24	2	1316.48	75	98736.00	
(Note only L1G is considered since the total storage requirement for L1R+IC is less than the storage requirement for L1G)							
LPGS Process related data				14.50	75	1087.50	
MSCD/PCD/metadata/CPF				11.06	75	829.50	
Total for temporary on-line storage						**100653**	**100.7**
Reprocessed Scenes							
# of Scene per day					3		
# of days (assuming reprocess will be done daily)					1		
L1G Image		658.24	2	1316.48	3	3949.44	
LPGS Process related data				14.50	3	43.50	
MSCD/PCD/metadata/CPF				11.06	3	33.18	
Total for reprocessed scenes						**4026.12**	**4.1**
Scene currently being processed							
Number of work order being processed in parallel					4		
Scene size (number of WRS scene per work order)					3		
0R data		404.83	1	404.83	12	4857.96	
IC data (0R)		71.16	1	71.16	12	853.92	
1R data (intermediate)		404.83	4	1619.32	12	19431.84	
IC data (1R)		71.16	4	284.64	12	3415.68	
L1G Image		658.24	2	1316.48	12	15797.76	
Geometric Grid				34.00	4	136.00	
MSCD/PCD/metadata/CPF				11.06	12	132.72	
LPGS Process related data				14.50	12	174.00	
Total for scene being processed						**44799.88**	**44.8**
Temporary storage for 0R Ingestion							
Number of work order					1		
Scene size (number of WRS scene per work order)					3		
0R data		404.83	1	404.83	3	1214.49	
IC data (0R)		71.16	1	71.16	3	213.48	
MSCD/PCD/metadata/CPF				11.06	3	33.18	
Total for 0R in queue						**1461.15**	**1.5**
0R in queue waiting for processing							
Number of work order being processed in parallel					4		
Scene size (number of WRS scene per work order)					3		
0R data		404.83	1	404.83	12	4857.96	
IC data (0R)		71.16	1	71.16	12	853.92	
MSCD/PCD/metadata/CPF				11.06	12	132.72	
Total for 0R in queue						**5844.6**	**5.9**

Table 5–6. Disk Storage Requirements for L1 Processing HWCI (Raw Data) (2 of 2)

Disk Storage for L1 Processing HWCI						
Type	Mega Pixels	Bytes/Pixel	Total Mega Bytes per item	Frequency/ Occurrence	Total Mega Bytes	**Total Giga Byte**
Data generated for anomaly analysis						
Anomaly requests (1 in process only)				1		
Average size of image (# of WRS scenes)				3		
0R data	404.83	1	404.83	3	1214.49	
IC data (0R)	71.16	1	71.16	3	213.48	
0Rc data	404.83	4	1619.32	3	4857.96	
IC data (0Rc)	71.16	4	284.64	3	853.92	
1R data	404.83	4	1619.32	3	4857.96	
IC data (1R)	71.16	4	284.64	3	853.92	
L1R Image	404.83	2	809.66	3	2428.98	
IC data (L1R)	71.16	2	142.32	3	426.96	
L1G Image	658.24	2	1316.48	3	3949.44	
MSCD/PCD/metadata/CPF			11.06	3	33.18	
LPGS process related data			14.50	3	43.50	
Total for data generated for anomaly analysis					**19733.79**	**19.8**
Total for L1 Processing HWCI						**176.8**

Table 5–7. Disk Storage Requirements for QA/AA HWCI (Raw Data)

Disk Storage for Quality Assessment/Anomaly Analysis HWCI						
Type	Mega Pixels	Bytes/Pixel	Mega Bytes per item	Frequency/ Occurrence	Mega Bytes	**Giga Byte**
Anomaly Analysis						
Anomaly requests (1 in process only)				1		
Average size of image (# of WRS scenes)				3		
Additional space for the one being analyzed (per scene)				5000	Mega Bytes	
0R data	404.83	1	404.83	3	1214.49	
IC data (0R)	71.16	1	71.16	3	213.48	
0Rc data	404.83	4	1619.32	3	4857.96	
IC data (0Rc)	71.16	4	284.64	3	853.92	
1R data	404.83	4	1619.32	3	4857.96	
IC data (1R)	71.16	4	284.64	3	853.92	
L1R Image	404.83	2	809.66	3	2428.98	
IC data (L1R)	71.16	2	142.32	3	426.96	
L1G Image	658.24	2	1316.48	3	3949.44	
MSCD/PCD/metadata/CPF			11.06	3	33.18	
LPGS process related data			14.50	3	43.50	
Additional space for the one being analyzed (per scene)			5000.00	1	5000.00	
Total for anomaly analysis					**24733.79**	**24.8**
Total for Quality Assessment/Anomaly Analysis HWCI						**24.8**

5.3.2 Spreadsheet Model Results—With Error Margins and Overheads

The raw data obtained in Section 5.2.2 do not include error margins, operating system overheads, and additional reserves required by the F&PRS. The raw data are summarized in Table 5–8 for the L1 Processing HWCI and in Table 5–9 for the QA/AA HWCI. These raw data are aggregated to obtain the total values. Please note that for the memory requirements, the maximum value among all steps and all bands is used as the total memory need. The memory requirements are driven by the radiometric processing and although the geometric processing does not require the entire band to be memory resident, it is still required for the radiometric processing.

The error margins, operating system/program overheads, and additional reserves are then added to the raw total values to yield the overall processing time, amount of data transfer for the FDDI and disk, and amount of memory and disk storage requirements. The results are shown in Table 5–10 for the L1 Processing HWCI and in Table 5–11 for the QA/AA HWCI. Please note that the total processing time combines the extrapolated processing time for the geometric processing and the processing time for the radiometric processing, which is calculated from the instruction counts and the CPU processing speed. Except for the disk storage, the calculations are made for individual bands and totaled for the entire scene. The CPU overheads due to data transfer for the FDDI and disk are not included in these tables.

5.3.3 Spreadsheet Model Results—Total Service Time

The total service time, which includes the processing time, CPU overheads due to data transfer, and data transfer time for nominal processing of one WRS scene with one CPU is about 92.8 minutes and is shown in Table 5–12. The time it takes to transfer data from the L1 Processing HWCI to the QA/AA HWCI for the anomaly analysis is about 33.2 minutes for one WRS scene and is shown in Table 5–13. This transfer time includes transferring all files such as 0R product, L1R product, L1G product, and all intermediate files to be used for analysis. Please note that the time it takes to display the image on the workstation is not included.

5.3.4 Spreadsheet Model Results—Disk and Memory Requirements

The disk and memory requirements for both the L1 Processing HWCI and QA/AA HWCI are summarized in Table 5–14. The total disk requirements are 232.05 GB for the L1 Processing HWCI and 32.55 GB for the QA/AA HWCI. Online storage of only one work order is assumed in the estimate of the disk storage requirements for the QA/AA HWCI.

The memory requirements for the L1 Processing HWCI are based on the amount of memory required for radiometric processing of Band 8 data. If multiple CPUs are to be configured and any of the CPUs need to be scheduled for radiometric processing of Band 8 data, then 1.383 GB of memory will be required for each of the CPUs in the L1 Processing HWCI.

Table 5–8. Summary of Results (Raw Data Without Error Margins, Overheads) for L1 Processing HWCI

Level 1 Processing HWCI (Nominal Processing) (Data Only) (no error margin, no operating system overhead)

		L1R Processing						L1G Processing		Format Product			
	Ingest Data	Step 1 0R Rad. Char.	Step 2 Pre-1R Correction	Step 3 0Rc Rad. Char.	Step 4 1R Correction	Step 5 1R Rad. Char/Cor	L1R QA	Steps 1&2 Ext Image/ Resample	L1G QA	Format Product	Final QA	Deliver Product	**Total**
Number of Operations (Mega Ops) (estimated) per WRS Scene													
Bands 1-5 & 7		1261.13	8721.63	1149.49	276.49	3213.58		[redacted]					**14622.32**
Band 6 (Lo & Hi)		319.14	2542.88	290.29	69.14	804.85		[redacted]					**4026.30**
Band 8		5013.94	66668.98	4575.05	1105.87	12842.56		[redacted]					**90206.40**
Total for 1 WRS Scene		12899.86	121541.64	11762.28	2833.95	32928.89		[redacted]					**181966.62**
Processing Time (seconds) (extrapolated from benchmark results) per WRS Scene													
Bands 1-5 & 7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	167.40	[redacted]	[redacted]	[redacted]	[redacted]	**167.40**
Band 6 (Lo & Hi)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	125.55	[redacted]	[redacted]	[redacted]	[redacted]	**125.55**
Band 8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	669.60	[redacted]	[redacted]	[redacted]	[redacted]	**669.60**
Total for 1 WRS Scene	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1799.55	[redacted]	[redacted]	[redacted]	[redacted]	**1799.55**
Memory Requirements (Mega Bytes)													
Bands 1-5 & 7	57.51	57.51	244.81	198.36	198.36	198.36	91.56	214.06	132.24	146.14	132.24	minimal	**244.81**
Band 6 (Lo & Hi)	22.68	22.68	70.66	59.04	59.04	59.04	32.32	134.24	132.24	135.72	132.24	minimal	**135.72**
Band 8	196.81	196.81	943.81	758.06	758.06	758.06	331.02	812.96	493.78	549.32	493.78	minimal	**943.81**
Overall													**943.81**
Disk IO (Mega Bytes) per WRS Scene													
Bands 1-5 & 7	139.35	46.45	187.30	187.30	187.30	280.20	82.00	405.68	122.68	270.16	122.68	135.08	**2166.18**
Band 6 (Lo & Hi)	34.86	11.62	47.98	47.98	47.98	71.22	22.76	194.34	122.68	249.32	122.68	124.66	**1098.08**
Band 8	557.25	185.75	747.00	747.00	747.00	1118.50	323.96	1604.58	486.72	1076.52	486.72	538.26	**8619.26**
Band Independent	33.18	11.06	0.00	11.06	0.00	11.06	11.06	11.06	11.06	22.12	11.06	11.06	**143.78**
Total for 1 WRS Scene	1461.39	487.13	1918.78	1929.84	1918.78	2881.98	849.78	4244.06	1356.54	2968.92	1356.54	1484.46	**22858.20**
FDDI IO (Mega Bytes) per WRS Scene													
Bands 1-5 & 7	46.45											135.08	**181.53**
Band 6 (Lo & Hi)	11.62											124.66	**136.28**
Band 8	185.75											538.26	**724.01**
Band Independent	11.06											11.06	**22.12**
Total for 1 WRS Scene	487.13											1484.46	**1971.59**
Disk Storage (Giga Bytes)													
Total													**176.80**

Table 5–9. Summary of Results (Raw Data Without Error Margins, Overheads) for QA/AA HWCI

Quality Assessment/Anomaly Analysis HWCI (Data Only) (no error margin, no operating system overhead)	
	Total
Disk IO (Megabytes) per WRS Scene	
Bands 1-5 & 7	633.63
Band 6 (Lo & Hi)	250.50
Band 8	2529.97
Band Independent	11.06
Total for 1 WRS Scene	6593.31
FDDI IO (Megabytes) per WRS Scene	
Bands 1-5 & 7	633.63
Band 6 (Lo & Hi)	250.50
Band 8	2529.97
Band Independent	11.06
Total for 1 WRS Scene	6593.31
Disk Storage (Gigabytes)	
Total	24.80

Table 5–10. Summary of Results (Data With Error Margins, Overheads) for L1 Processing HWCI

Level 1 Processing HWCI (Nominal Processing) (with error margin and operating system overhead)									
	Total without Error Margin Overhead	Error Margin	Total with Error Margin	Operating System Overhead	Total with Error Margin & O/S & Pgm	Additional Requirement per F&PRS	Total with Additional Requirement	**Overall**	
Number of Operations (Mega Ops) (estimated) per WRS Scene									
Bands 1-5 & 7	14622.32	50%	21933.48	0	21933.48				
Band 6 (Lo & Hi)	4026.30	50%	6039.45	0	6039.45				
Band 8	90206.40	50%	135309.60	0	135309.60				
Total for 1 WRS Scene	181966.62	50%	272949.93	0	272949.93				
Processing Time (seconds) (extrapolated from benchmark results) per WRS Scene									
Bands 1-5 & 7	167.40	0%	167.40	0	167.40				
Band 6 (Lo & Hi)	125.55	0%	125.55	0	125.55				
Band 8	669.60	0%	669.60	0	669.60				
Total for 1 WRS Scene	1799.55	0%	1799.55	0	1799.55				
Total Processing Time (seconds) per WRS Scene		**0.0102564**	**micro seconds/ops**						
(Estimated number of ops * processing speed + extrapolated benchmark result)									
Bands 1-5 & 7			392.36		392.36	0%	392.36		
Band 6 (Lo & Hi)			187.49		187.49	0%	187.49		
Band 8			2057.39		2057.39	0%	2057.39		
Total for 1 WRS Scene			4599.04		4599.04	0%	4599.04	**4599.04**	**76.65 minutes**
Memory Requirements (Megabytes)									
Bands 1-5 & 7	244.81	5%	257.05	115	372.05	25%	465.06		
Band 6 (Lo & Hi)	135.72	5%	142.51	115	257.51	25%	321.88		
Band 8	943.81	5%	991.00	115	1106.00	25%	1382.50		
Overall	943.81	5%	991.00	115	1106.00	25%	1382.50	**1382.50**	**Mega Bytes**
Disk IO (Megabytes) per WRS Scene									
Bands 1-5 & 7	2166.18	10%	2382.80	0	2382.80	0%	2382.80		
Band 6 (Lo & Hi)	1098.08	10%	1207.89	0	1207.89	0%	1207.89		
Band 8	8619.26	10%	9481.19	0	9481.19	0%	9481.19		
Band Independent	143.78	10%	158.16	0	158.16	0%	158.16		
Total for 1 WRS Scene	22858.20	10%	25144.02	0	25144.02	0%	25144.02	**25144.02**	**Mega Bytes**
FDDI IO (Megabytes) per WRS Scene									
Bands 1-5 & 7	181.53	10%	199.68	0	199.68	0%	199.68		
Band 6 (Lo & Hi)	136.28	10%	149.91	0	149.91	0%	149.91		
Band 8	724.01	10%	796.41	0	796.41	0%	796.41		
Band Independent	22.12	10%	24.33	0	24.33	0%	24.33		
Total for 1 WRS Scene	1971.59	10%	2168.75	0	2168.75	0%	2168.75	**2168.75**	**Mega Bytes**
Disk Storage (Gigabytes)									
Total	176.80	5%	185.64	0.00	185.64	25%	232.05	**232.05**	**Giga Bytes**

Table 5–11. Summary of Results (Data With Error Margins, Overheads) for QA/AA HWCI

Quality Assessment/Anomaly Analysis HWCI (with error margin and operating system overhead)									
	Total without Error Margin Overhead	Error Margin	Total with Error Margin	Operating System Overhead	Total with Error Margin & O/S & Pgm	Additional Requirement per F&PRS	Total with Additional Requirement	**Overall**	
Memory Requirements (Megabytes)									
Overall								**128.00**	**Megabytes**
Disk IO (Megabytes) per WRS Scene									
Bands 1-5 & 7	633.63	10%	696.99	0	696.99	0%	696.99		
Band 6 (Lo & Hi)	250.50	10%	275.55	0	275.55	0%	275.55		
Band 8	2529.97	10%	2782.97	0	2782.97	0%	2782.97		
Band Independent	11.06	10%	12.17	0	12.17	0%	12.17		
Total for 1 WRS Scene	6593.31	10%	7252.64	0	7252.64	0%	7252.64	**7252.64**	**Megabytes**
FDDI IO (Megabytes) per WRS Scene									
Bands 1-5 & 7	633.63	10%	696.99	0	696.99	0%	696.99		
Band 6 (Lo & Hi)	250.50	10%	275.55	0	275.55	0%	275.55		
Band 8	2529.97	10%	2782.97	0	2782.97	0%	2782.97		
Band Independent	11.06	10%	12.17	0	12.17	0%	12.17		
Total for 1 WRS Scene	6593.31	10%	7252.64	0	7252.64	0%	7252.64	**7252.64**	**Megabytes**
Disk Storage (Gigabytes)									
Total	24.80	5%	26.04	0.00	26.04	25%	32.55	**32.55**	**Gigabytes**

Table 5–12. Total Service Time for Processing One WRS Scene With One CPU

Level 1 Processing HWCI (Nominal Processing) - Process/Data Transfer Time						
(for 1 WRS Scene)			**CPU performance degradation factor = 0%**			
in minutes	**Ingest Data**	**L1R Process**	**L1G Process**	**Format Product**	**Deliver Product**	**Total**
CPU Time						
Application	negligible	46.66	29.99	negligible	negligible	76.65
Overhead associated with FDDI data transfer	0.24	0.00	0.00	0.00	0.73	0.97
Overhead associated with RAID data transfer	0.27	1.88	1.05	0.81	0.28	4.30
Total	***0.51***	***48.54***	***31.05***	***0.81***	***1.01***	***81.91***
Data Transfer Time						
FDDI	1.19	0.00	0.00	0.00	3.63	4.82
RAID	0.38	2.62	1.47	1.13	0.39	5.99
Total	***1.57***	***2.62***	***1.47***	***1.13***	***4.02***	***10.81***
Total	**2.09**	**51.15**	**32.51**	**1.95**	**5.02**	**92.72**

Table 5–13. Time for Transferring One WRS Scene to the QA/AA HWCI for Non-nominal Processing

Quality Assessment/Anomaly Analysis HWCI - Data Transfer Time (for 1 WRS Scene)			
	Time (seconds)	**Time (minutes)**	**Data Volume (Mega Byte)**
FDDI data transfer	967.02	**16.12**	7252.64
RAID disk transfer	103.61	**1.73**	7252.64
W/S O2 disk transfer	362.63	**6.04**	7252.64
Origin 2000 CPU O/H associated with FDDI data transfer	193.65	**3.23**	7252.64
Origin 2000 CPU O/H associated with disk data transfer	74.39	**1.24**	7252.64
W/S O2 CPU O/H associated with FDDI data transfer	193.65	**3.23**	7252.64
W/S O2 CPU O/H associated with disk data transfer	96.70	**1.61**	7252.64
Total	1991.64	**33.19**	

Table 5–14. Memory and Disk Storage Requirements

Storage Requirements (including 25% reserve)					
	L1 Processing HWCI		**QA/AA HWCI**		
Memory Requirements	**1382.50**	**M Bytes**	**128.00**	**M Bytes**	
Disk Space Requirements	**232.05**	**G Bytes**	**32.55**	**G Bytes**	1 work order for anomaly analysis only

6. Summary and Conclusions

As shown in Table 5–12, the total service time for the nominal processing of one WRS scene, assuming that the average instruction takes two CPU cycles to execute, is about 92.8 minutes. The service time includes 82.0 minutes of the CPU time, 4.8 minutes of the FDDI data transfer time, and 6.0 minutes of the disk transfer time. To meet the requirement of processing 28 WRS scenes a day and some non-nominal processing requests, at least three CPUs will be required. It is assumed that four CPUs will be in the LPGS baseline configuration. The CPU performance will degrade slightly with increasing numbers of CPUs. Assuming a 7-percent degradation for a four-CPU configuration, the total service time will increase from 92.8 minutes to 98.9 minutes. Table 6–1 shows the total service time for the nominal processing of one WRS scene with a 7-percent CPU performance degradation. Similarly, the time it takes to transfer one WRS scene from the L1 Processing HWCI to the QA/AA HWCI will increase from 33.20 minutes to 33.53 minutes and is shown in Table 6–2.

Unless otherwise specified, a 7-percent CPU performance degradation will be assumed for the L1 Processing HWCI in the following discussions.

Table 6–1. Total Service Time for Processing One WRS Scene With 7-Percent CPU Performance Degradation

Level 1 Processing HWCI (Nominal Processing) - Process/Data Transfer Time						
(for 1 WRS Scene) CPU performance degradation factor = 7%						
in minutes	**Ingest Data**	**L1R Process**	**L1G Process**	**Format Product**	**Deliver Product**	**Total**
CPU Time						
Application	negligible	50.17	32.25	negligible	negligible	82.42
Overhead associated with FDDI data transfer	0.26	0.00	0.00	0.00	0.78	1.04
Overhead associated with RAID data transfer	0.30	2.02	1.13	0.87	0.30	4.62
Total	***0.55***	***52.19***	***33.38***	***0.87***	***1.08***	***88.08***
Data Transfer Time						
FDDI	1.19	0.00	0.00	0.00	3.63	4.82
RAID	0.38	2.62	1.47	1.13	0.39	5.99
Total	***1.57***	***2.62***	***1.47***	***1.13***	***4.02***	***10.81***
Total	**2.13**	**54.80**	**34.85**	**2.01**	**5.10**	**98.89**

Table 6–2. Time for Transferring One WRS Scene to QA/AA HWCI With 7-Percent CPU Performance Degradation for Origin 2000

Quality Assessment/Anomaly Analysis HWCI - Data Transfer Time (for 1 WRS Scene) CPU performance degradation factor = 7% for Origin 2000				
	Performance Degradation Factor	**Time (seconds)**	**Time (minutes)**	**Data Volume (Megabyte)**
FDDI data transfer	0%	967.02	**16.12**	7252.64
RAID disk transfer	0%	103.61	**1.73**	7252.64
W/S O2 disk transfer	0%	362.63	**6.04**	7252.64
Origin 2000 CPU O/H associated with FDDI data transfer	7%	208.22	**3.47**	7252.64
Origin 2000 CPU O/H associated with disk data transfer	7%	79.99	**1.33**	7252.64
W/S O2 CPU O/H associated with FDDI data transfer	0%	193.65	**3.23**	7252.64
W/S O2 CPU O/H associated with disk data transfer	0%	96.70	**1.61**	7252.64
Total		2011.81	**33.53**	

6.1 Resource Utilization for Four-CPU Configuration

The resource utilization with a four-CPU configuration is shown in Table 6–3. For the disk I/O, the utilization does not include disk I/O for displaying images for the automatic quality assessment.

Table 6–3. Resource Utilization for a Four-CPU Configuration

			CPU performance degradation factor = 7%	
HWCI/	**Resource**	**Nominal Processing 28 WRS Scenes a Day (including reprocessing of 3 WRS scenes)**	**Non-nominal Processing 3 WRS Scenes a Day (Benchmark & Diagnostic Runs only)**	**Total**
L1 Processing HWCI				
	CPU (4 CPUs)	42.82%	9.68%	52.50%
	FDDI	9.37%	6.72%	16.09%
	Disk I/O	11.64%	3.21%	14.85%
QA/AA HWCI (one workstation)				
	CPU		0.45%	0.45%
	Disk I/O		3.37%	3.37%

6.2 Processing Scenarios

Even though the compiler can optimize the code for multiprocessor systems, to fully take advantage of multiple CPUs, the application software needs to be designed to allow parallel processing on the data. Depending on the degree of parallel processing of the application software, the following different processing scenarios could arise.

6.2.1 Scenario 1: Sequential Processing of All Bands, One Band After Another

This scenario assumes that the application software does not provide the capability for simultaneously processing different bands of the same work order. Therefore, all bands from the same work order can only be processed sequentially. To take advantage of multiple CPUs, multiple work orders need to be processed simultaneously, one on each CPU. This scenario will not require any synchronization and can be supported by the current software design.

6.2.2 Scenario 2: Process Multiple Bands Simultaneously

This scenario assumes that parallel processing can be done on different bands of the same work order on different CPUs simultaneously. Because Band 8 takes almost four times longer to process, the bottleneck for processing a WRS scene is in the processing of this band. Table 6–4 shows the amount of time it takes to process a single band of data. Note that the Ingest Data, Format Product, and Deliver Product are for the entire scene; Table 6–4 shows no breakdown for these three processes.

This scenario will require some synchronization before the next processes, such as L1G Processing and Format Product, can proceed. However, the current design of the radiometric processing can not support this scenario without design changes.

Table 6–4. Nominal Processing Time by Band for One WRS Scene

Level 1 Processing HWCI (Normal Processing) - Process/Data Transfer Time (by band for 1 CPU) CPU performance degradation factor=7%							
in minutes	**# of Occur-rences**	**Ingest Data**	**L1R Process**	**L1G Process**	**Format Product**	**Deliver Product**	**Total for All Bands**
CPU Time							
Band 1/2/3/4/5/7	6		4.24	3.11			44.10
Band 6	1		1.17	2.32			3.49
Band 8	1		25.66	12.43			38.09
All Bands	1	0.55			0.87	1.08	2.50
Data Transfer Time							
Band 1/2/3/4/5/7	6		0.27	0.14			2.46
Band 6	1		0.08	0.09			0.17
Band 8	1		1.02	0.55			1.57
All Bands	1	1.57			1.13	4.02	6.72
Total		2.12	54.99	34.89	2.00	5.10	

6.2.3 Scenario 3: Parallel Processing Within a Band

This scenario will provide a maximum flexibility in processing the data. But it will require that the software be able to break the data and work to allow parallel processing (or multithreading) on data within a band. It allows data and work for a band being processed by multiple CPUs simultaneously. There will be additional overhead due to the necessary synchronization of processes. Total service time may increase slightly due to the overhead but the total clock time to process a band of data can be significantly reduced. Another advantage of this scenario is that the memory requirements can be significantly reduced. 1.383 GB of memory for the entire system (instead of 1.383 GB per CPU) will be sufficient if all CPUs are processing the same band of data simultaneously. Additional memory will allow processing of multiple bands or multiple work orders simultaneously without the data being unnecessarily swapped in and out.

The current geometric processing software design supports this scenario. Furthermore it does not require the entire band of data to be resident in the memory. It allows processing on smaller amounts of data within a band (e.g., 150 scans of data). This capability further reduces the 1.383 GB of memory requirements for the geometric processing.

The current design of the radiometric processing can not support this scenario without design changes.

6.2.4 Discussion

Table 6–5 shows the minimum clock times for different combinations of the above scenarios. These minimum clock times are derived from the data in Table 6–4. Clock times corresponding to the scenarios supported by the current software design are shown in ***Italic Bold***. Please note that the clock time estimated in Table 6–5 is assuming that only one work order is being processed in a four-CPU configuration. The clock time will significantly increase if any other jobs in addition to the work order are running on the system.

In the actual situation with multiple CPUs, the operating system will schedule many jobs (either of the same work orders or different work orders) simultaneously. Each job will get a slice of total CPU time. As the number of jobs increases, the clock time to complete each job increases. The number of work orders/bands that can be processed simultaneously is determined by the amount of memory available. Insufficient memory will result in the data being swapped in and out unnecessarily, which is very inefficient for the size of the data processed by the LPGS.

With the assumption that 6 GB of memory will be available for the LPGS, simultaneous processing of four work orders will require no data swapping. However, the CPUs may not be fully utilized during data transfer. The optimum number of work orders that can be processed simultaneously is initially determined to be about six.

Table 6–5. Minimum Clock Times for Processing One WRS Scene With Different Scenarios in a Four-CPU Configuration

Radiometric Processing	Geometric Processing: Scenario 1 — Sequential processing, one band after another	Geometric Processing: Scenario 2 — Processing multiple bands simultaneously	Geometric Processing: Scenario 3 — Parallel processing within a band
Scenario 1 Sequential processing, one band after another	***98.89 minutes***	***77.00 minutes (1)***	***73.86 minutes (2)***
Scenario 2 Processing multiple bands simultaneously	70.75 minutes (3)	48.88 minutes (4)	39.56 minutes (5)
Scenario 3 Parallel processing within a band	59.90 minutes (6)	37.99 minutes (7)	34.84 minutes (8)

Notes:

(1) (2.12+54.80+12.43+0.55+2.00+5.10) (bottleneck: radiometric processing, geometric processing of Band 8 data)

(2) (2.12+54.80+(3.11*6+2.32+12.43)/4+(0.14*6+0.09+0.55)+2.00+5.10) (bottleneck: radiometric processing)

(3) (2.12+25.66+1.02+34.85+2.00+5.10) (bottleneck: radiometric processing of Band 8 data and geometric processing)

(4) (2.12+25.66+1.02+12.43+0.55+2.00+5.10) (bottleneck: processing of Band 8 data)

(5) (2.12+25.66+1.02+12.43/4+0.55+2.00+5.10) (bottleneck: radiometric processing of Band 8 data)

(6) (2.12+(4.24*6+1.17+25.66)/4+(0.27*6+0.08+1.02)+34.89+2.00+5.10) (bottleneck: geometric processing)

(7) (2.12+(4.24*6+1.17+25.66)/4+(0.27*6+0.08+1.02)+12.43+0.55+2.00+5.10) (bottleneck: geometric processing of Band 8 data)

(8) (2.12+(44.10+3.49+38.09)/4+(2.46+0.17+1.57)+2.00+5.10)

6.3 Baseline Workload—28 WRS Scenes a Day

Regardless of which scenario is chosen, if 0R products are always available for processing, 12.8 hours will be necessary to process 28 WRS scenes if 4 CPUs are used or 16.3 hours if 3 CPUs are used (assuming that CPU processing overlaps the I/O device about 50 percent.)

As shown in Table 5–14, the total disk space required is 233 GB for the L1 Processing HWCI and 33 GB for the QA/AA HWCI. Online storage of only one work order is assumed in the estimate of the disk space for the QA/AA HWCI. For the memory requirements, 1.4 GB will be required for each of the CPUs or a total of 5.6 GB (for four CPUs) will be required for the L1 Processing HWCI. Similarly, 128 MB of the memory will be required for each workstation in the QA/AA HWCI.

As shown in Table 6–3, the utilization for the FDDI and disk I/O is relative low and will not cause any concerns for this workload.

6.4 Increased LPGS Workload

This section briefly discusses the resource requirements to handle an increased workload. Table 6–6 summarizes the resources required for the different workloads. Table 6–7 shows the corresponding resource utilization for the L1 Processing HWCI. It is assumed that the number of non-nominal processing requests will remain the same (three WRS scenes a day) even though the workload changes.

Table 6–6. Resource Requirements With Different Workloads

			L1 Processing HWCI		QA/AA HWCI	
Number of WRS Scenes per Day	**Number of Reprocessed WRS Scenes per Day**	**Proposed Number of CPUs**	**Disk Storage (GB) Total**	**Memory (GB)**	**Disk Storage (GB)**	**Memory (MB) per Workstation**
25	3	4	233	5.6	33	128
50	5	8	435	11.2	33	128
75	8	12	639	16.8	33	128
100	10	16	841	22.4	33	128

Table 6–7. L1 Processing HWCI Resource Utilization With Different Workloads

Number of WRS Scenes per day	Number of Reprocessed WRS Scenes per day	Number of Non-nominal Requests (WRS Scenes per day)	Proposed Number of CPUs	CPU Performance Degradation Factor	CPU Utilization	FDDI Utilization	Disk i/o Utilization
1			1	0%	5.688%	0.335%	0.416%
		1	1	0%	11.997%	2.238%	1.071%
25	3	3	4	7%	52.49%	16.09%	14.85%
50	5	3	8	10%	48.45%	25.12%	26.08%
75	8	3	12	10%	47.05%	34.49%	37.72%
100	10	3	16	10%	45.95%	43.53%	48.95%

6.5 Sensitivity Analysis

The sensitivity analysis is conducted for two factors: the number of CPU cycles for average instructions and the scene size.

6.5.1 Number of CPU Cycles for Average Instructions

The assumption of the CPU speed for average instructions plays a significant role in the total service time estimate. Table 6–8 shows the total service time with various assumptions on the number of CPU cycles for average instructions for the nominal processing. Table 6–9 shows the corresponding CPU utilization for the Level 1 processing HWCI. As discussed in Section 4.5.3, this analysis assumes two cycles per instruction. Table 6–9 shows that even for four cycles per instruction, the four CPUs of the Level 1 processing HWCI is 68 percent utilized for the baseline workload (nominal processing of 28 WRS scenes).

Table 6–8. Total Service Time for One WRS Scene As a Function of CPU Cycles per Instruction

Total Service time as a Function of CPU Cycles Per Instruction (For 1 WRS Scene)	**CPU performance degradation factor = 7%**				
# of cycles/average instruction	1	2	3	4	5
Equivalent MFLOPS	195	97.5	65	48.75	39
Processing time (microseconds/instruction)	0.0051	0.0102	0.0153	0.0205	0.0256
For One WRS Scene	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**
CPU Time					
Application	57.34	82.42	107.51	132.59	157.68
Overhead associated with FDDI data transfer	1.04	1.04	1.04	1.04	1.04
Overhead associated with RAID data transfer	4.62	4.62	4.62	4.62	4.62
Total	**62.99**	**88.08**	**113.16**	**138.25**	**163.33**
Data Transfer Time					
FDDI	4.82	4.82	4.82	4.82	4.82
RAID	5.99	**5.99**	**5.99**	**5.99**	5.99
Total	**10.81**	**10.81**	**10.81**	**10.81**	**10.81**
Total	**73.80**	**98.89**	**123.97**	**149.06**	**174.14**

Table 6–9. CPU Utilization as a Function of CPU Cycles per Instruction

CPU Utilization as a Function of CPU Cycles Per Instruction (for 28 full WRS Scenes)	**CPU performance degradation factor = 7%**				
# of cycles/average instruction	1	2	3	4	5
Equivalent MFLOPS	195	97.5	65	48.75	39
Processing time (microseconds/instruction)	0.0051	0.0102	0.0153	0.0205	0.0256
CPU Utilization (4 CPUs)	**30.62%**	**42.82%**	**55.01%**	**67.20%**	**79.40%**

6.5.2 Scene Size

The estimates of instruction counts and amount of data transferred are calculated based on one full WRS scene being processed. The LPGS has a requirement to generate Level 1 images corresponding to a partial ETM+ subinterval up to three WRS scenes. Processing two one-half WRS scenes will require more overhead than processing one full WRS scene. Comparisons of the amount of data transferred are shown in Tables 6–10 and 6–11 for nominal processing and non-nominal processing, respectively. For two one-half WRS scenes, the amount of the data transferred increases slightly (0.94 percent for the nominal processing and 0.2 percent for the non-nominal processing) as compared to one full WRS scene.

Comparisons of instruction counts are shown in Table 6–12. Processing two one-half WRS scene will require 11.59 percent more instructions for the radiometric processing than for processing one full WRS scene. This increase is mainly due to the memory effect correction. Excluding the memory effect correction only an additional 0.13 percent instructions are required. The memory effect correction algorithm uses a logic of 3,000 loops (6000 for Band 8) to construct a vector of 3,000 coefficients (6,000 for Band 8) for each detector, which is independent of the scene size.

Table 6–13 shows the total service time with various assumptions on the number of CPU cycles for average instructions for nominal processing one-half of a WRS scene. Table 6–14 shows the corresponding CPU utilization for the Level 1 processing HWCI. As discussed in Section 4.5.3, this analysis assumes two cycles per instruction. Table 6–14 shows that with two cycles per instruction, the CPUs of the Level 1 processing HWCI are about 46 percent utilized for the baseline workload (nominal processing of 28 scenes) assuming all the scenes being processed are one-half of a WRS scene in size. The CPUs are 73 percent utilized if four cycles per instruction is assumed.

6.5.3 Combination of CPU Cycles per Instruction and Scene Size

Combining the results from Sections 6.5.1 and 6.5.2, Figure 6–1 shows the CPU utilization for the nominal processing of the 28 WRS scenes with 4 CPUs as a function of CPU cycles per instruction and scene size. Figure 6–2 shows the CPU utilization with three non-nominal processing requests (for a total of three WRS scenes) added. As required by the F&PRS to provide at least 110 percent of the processing throughput capability required to satisfy the worst-case processing loading, the CPU utilization should be kept under 80 percent. Figure 6–2 shows that the CPUs can be kept less than 75 percent utilized; even the LPGS software only achieves 65 MFLOPS (three cycles per instruction).

The utilization of FDDI and disk I/O is relatively constant with respect to the scene size and MFLOPS.

Table 6–10. Disk I/O for Different Scene Sizes for Nominal Processing (1 of 2)

Disk I/O for Nominal Processing				
	1 WRS Scene (Megabytes)	**1 1/2 WRS Scene (Megabytes)**	**2 1/2 WRS Scenes (Megabytes)**	**Ratio 2 1/2 WRS to 1 WRS**
Ingest Data				
Write 0R Data to disk	404.86	202.43	404.86	100.00%
Write IC Data (0R) to disk	71.21	35.64	71.28	100.10%
Write MSCD/PCD/Meta/CPF to disk	11.06	11.06	22.12	200.00%
Read 0R Data into memory	404.86	202.43	404.86	100.00%
Read IC Data (0R) into memory	71.21	35.64	71.28	100.10%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write 0R Data to input directory	404.86	202.43	404.86	100.00%
Write IC Data (0R) to input directory	71.21	35.64	71.28	100.10%
Write MSCD/PCD/Meta/CPF to input directory	11.06	11.06	22.12	200.00%
Total for Ingestion	**1461.4**	**747.4**	**1494.8**	**102.28%**
Level 1R Process				
Process # 1				
Step 1 0R Radiometric Characterization				
Read 0R Data into memory	404.86	202.43	404.86	100.00%
Read IC Data (0R) into memory	71.21	35.64	71.28	100.10%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Total for Step 1	**487.1**	**249.1**	**498.3**	**102.28%**
Step 2 Pre-1R Correction				
Write 0Rc Data to disk	1619.44	809.72	1619.44	100.00%
Write IC Data (0Rc) to disk	284.84	142.56	285.12	100.10%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Step 2	**1918.8**	**959.5**	**1919.1**	**100.01%**
Process # 2				
Step 3 0Rc Radiometric Characterization/Calibration				
Read 0Rc Data into memory	1619.44	809.72	1619.44	100.00%
Read IC Data (0Rc) into memory	284.84	142.56	285.12	100.10%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Step 3	**1929.8**	**970.6**	**1941.2**	**100.59%**
Step 4 1R Correction				
Write 1R Data to disk	1619.44	809.72	1619.44	100.00%
Write IC Data (1R) to disk	284.84	142.56	285.12	100.10%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Step 4	**1918.8**	**959.5**	**1919.1**	**100.01%**
Process # 3				
Step 5 1R Radiometric Characterization/Correction				
Read 1R Data into memory	1619.44	809.72	1619.44	100.00%
Read IC Data (1R) into memory	284.84	142.56	285.12	100.10%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write L1R Data to disk	809.72	404.86	809.72	100.00%
Write IC Data (L1R) to disk	142.42	71.28	142.56	100.10%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Step 5	**2882.0**	**1446.7**	**2893.5**	**100.40%**
Total for 1R Processing	**9136.5**	**4585.5**	**9171.0**	**100.38%**
QA for L1R				
Read LPGS Process related data into memory	14.50	7.25	14.50	100.00%
Read L1R Data into memory	809.72	404.86	809.72	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for L1R QA	**849.8**	**430.4**	**860.8**	**101.30%**

Table 6–10. Disk I/O for Different Scene Sizes for Nominal Processing (2 of 2)

	Disk I/O for Nominal Processing			
	1 WRS Scene (Megabytes)	**1 1/2 WRS Scene (Megabytes)**	**2 1/2 WRS Scenes (Megabytes)**	**Ratio 2 1/2 WRS to 1 WRS**
Level 1G Process				
Step 1 Create Extended Image				
Read 1R Data into memory	809.72	404.86	809.72	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write Extended Image to disk**	1012.15	506.08	1012.15	100.00%
(** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)				
Write Geometric Grid to disk	34.00	34.00	68.00	200.00%
Total for Step 1	**1866.9**	**956.0**	**1912.0**	**102.41%**
Step 2 Resample				
Read Extended image into memory**	1012.15	506.08	1012.15	100.00%
(** Conversion factor of 2.5 = 2*1.25 to account for 25% added lines and 2 bytes)				
Read Geometric Grid into memory	34.00	34.00	68.00	200.00%
Write L1G Data to disk	1316.48	658.24	1316.48	100.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Step 2	**2377.1**	**1205.6**	**2411.1**	**101.43%**
Total for 1G Processing	**4244.1**	**2161.6**	**4323.1**	**101.86%**
QA for L1G				
Read LPGS Process related data into memory	14.50	7.25	14.50	100.00%
Read L1G Data into memory	1316.48	658.24	1316.48	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for L1G QA	**1356.5**	**683.8**	**1367.6**	**100.82%**
Format Product				
Read L1G Data into memory	1316.48	658.24	1316.48	100.00%
Read IC Data (L1R) into memory	142.42	71.28	142.56	100.10%
Read LPGS Process related data into memory	14.50	7.25	14.50	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write L1G Data to output directory	1316.48	658.24	1316.48	100.00%
Write IC Data (L1R) to output directory	142.42	71.28	142.56	100.10%
Write LPGS Process related data to output directory	14.50	7.25	14.50	100.00%
Write MSCD/PCD/Meta/CPF to output directory	11.06	11.06	22.12	200.00%
Total for Format Product	**2968.9**	**1495.7**	**2991.3**	**100.75%**
Final QA				
Read LPGS Process related data into memory	14.50	7.25	14.50	100.00%
Read L1G Data into memory	1316.48	658.24	1316.48	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for Final QA	**1356.5**	**683.8**	**1367.6**	**100.82%**
Deliver Product				
Read L1G Data from Disk	1316.48	658.24	1316.48	100.00%
Read IC Data (L1G) from disk	142.42	71.28	142.56	100.10%
Read LPGS Process related data from disk	14.50	7.25	14.50	100.00%
Read MSCD/PCD/Meta/CPF from disk	11.06	11.06	22.12	200.00%
Total for Deliver Product	**1484.5**	**747.8**	**1495.7**	**100.75%**
Grand Total	**22858.2**	**11536.0**	**23071.9**	**100.94%**

Table 6–11. Disk I/O for Different Scene Sizes for Non-nominal Processing

Disk I/O for Anomaly Analysis				
	1 WRS Scene (Megabytes)	1 1/2 WRS Scene (Megabytes)	2 1/2 WRS Scenes (Megabytes)	Ratio 2 1/2 WRS to 1 WRS
AAS				
Read 0R Data into memory	404.86	202.43	404.86	100.00%
Read IC Data (0R) into memory	71.21	35.64	71.28	100.10%
Read LPGS Process related data into memory	14.50	7.25	14.50	100.00%
Read 0Rc Data into memory	1619.44	809.72	1619.44	100.00%
Read IC Data (0Rc) into memory	284.84	142.56	285.12	100.10%
Read 1R Data into memory	1619.44	809.72	1619.44	100.00%
Read IC Data (1R) into memory	284.84	142.56	285.12	100.10%
Read L1R Data into memory	809.72	404.86	809.72	100.00%
Read IC Data (L1R) into memory	142.42	71.28	142.56	100.10%
Read L1G Data into memory	1316.48	658.24	1316.48	100.00%
Read MSCD/PCD/Meta/CPF into memory	11.06	11.06	22.12	200.00%
Write LPGS Process related data to disk	14.50	7.25	14.50	100.00%
Total for AAS	**6593.3**	**3302.6**	**6605.1**	**100.18%**

Table 6–12. Instruction Counts for Different Scene Sizes for Radiometric Processing

Instruction Counts for Radiometric Processing				
	1 WRS Scene (Mega Ops)	1 1/2 WRS Scene (Mega Ops)	2 1/2 WRS Scenes (Mega Ops)	Ratio 2 1/2 WRS to 1 WRS
2.1 Characterize Impulse Noise	1295.005	647.542	1295.085	100.01%
2.3 Locate Scan-Correlated Shift (SCS)	4577.465	2288.772	4577.545	100.00%
2.5 Characterize Dropped Lines	857.737	428.908	857.817	100.01%
2.6a Characterize Detector Saturation (A/D)	2927.279	1463.680	2927.359	100.00%
2.6b Characterize Detector Saturation (Analog)	2927.277	1463.679	2927.357	100.00%
2.10a Histogram Analysis (Integer Operations)	3242.307	1623.036	3246.073	100.12%
2.10b Histogram Analysis (Floating Point Operations)	6560.877	3322.339	6644.678	101.28%
3.4.1 Process IC Data - Emissive Band	2958.773	1479.466	2958.933	100.01%
3.4.2 Process IC Data - Reflective Band	2595.719	1297.953	2595.906	100.01%
4.1.1 Combine Image and IC Data	1903.909	951.975	1903.949	100.00%
4.1.2 Correct Memory Effect (new from Dennis Helder)	113639.153	67319.422	134638.843	118.48%
4.1.3 Apply Scan-Correlated Shift (SCS)	1714.681	857.380	1714.761	100.00%
4.1.4 Apply Coherent Noise Correction	2379.955	1190.038	2380.075	100.01%
4.1.6 Separate Image and IC Data	1903.908	951.974	1903.948	100.00%
4.2 Apply Radiometric Correction	2833.801	1416.941	2833.881	100.00%
4.3.1 Correct Dropped Lines	662.049	331.064	662.129	100.01%
4.3.2 Correct Inoperable Detectors	0.437	0.437	0.874	200.00%
4.3.4 Correct Stripping	809.851	405.034	810.068	100.03%
4.3.5 Correct Banding	28175.364	14087.722	28175.444	100.00%
6.5 Gain Switch and Apply Relative Gain Correction	0.107	0.107	0.215	200.00%
TOTAL	181965.656	101527.470	203054.940	111.59%
Total (excluding memory effect correction)	68326.502	34208.049	68416.097	100.13%

Table 6–13. Total Service Time for One-Half WRS Scene As a Function of CPU Cycles per Instruction

Total Service time as a Function of CPU Cycles Per Instruction (For 1/2 WRS Scene)	CPU performance degradation factor = 7%				
# of cycles/average instruction	1	2	3	4	5
Equivalent MFLOPS	195	97.5	65	48.75	39
Processing time (microseconds/instruction)	0.0051	0.0102	0.0153	0.0205	0.0256
For 1/2 WRS Scene	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**	**Time (minutes)**
CPU Time					
Application	30.12	44.12	58.11	72.11	86.11
Overhead associated with FDDI data transfer	0.52	0.52	0.52	0.52	0.52
Overhead associated with RAID data transfer	2.33	2.33	2.33	2.33	2.33
Total	**32.98**	**46.97**	**60.97**	**74.97**	**88.96**
Data Transfer Time					
FDDI	2.44	2.44	2.44	2.44	2.44
RAID	3.02	3.02	3.02	3.02	3.02
Total	**5.46**	**5.46**	**5.46**	**5.46**	**5.46**
Total	**38.44**	**52.43**	**66.43**	**80.43**	**94.42**

Table 6–14. CPU Utilization as a Function of CPU Cycles per Instruction for 28 x 2 One-Half WRS Scenes

CPU Utilization as a Function of CPU Cycles Per Instruction (for 28x2 1/2 WRS Scenes)	CPU performance degradation factor = 7%				
# of cycles/average instruction	1	2	3	4	5
Equivalent MFLOPS	195	97.5	65	48.75	39
Processing time (microseconds/instruction)	0.0051	0.0102	0.0153	0.0205	0.0256
CPU Utilization (4 CPUs)	32.06%	45.67%	59.28%	72.88%	86.49%

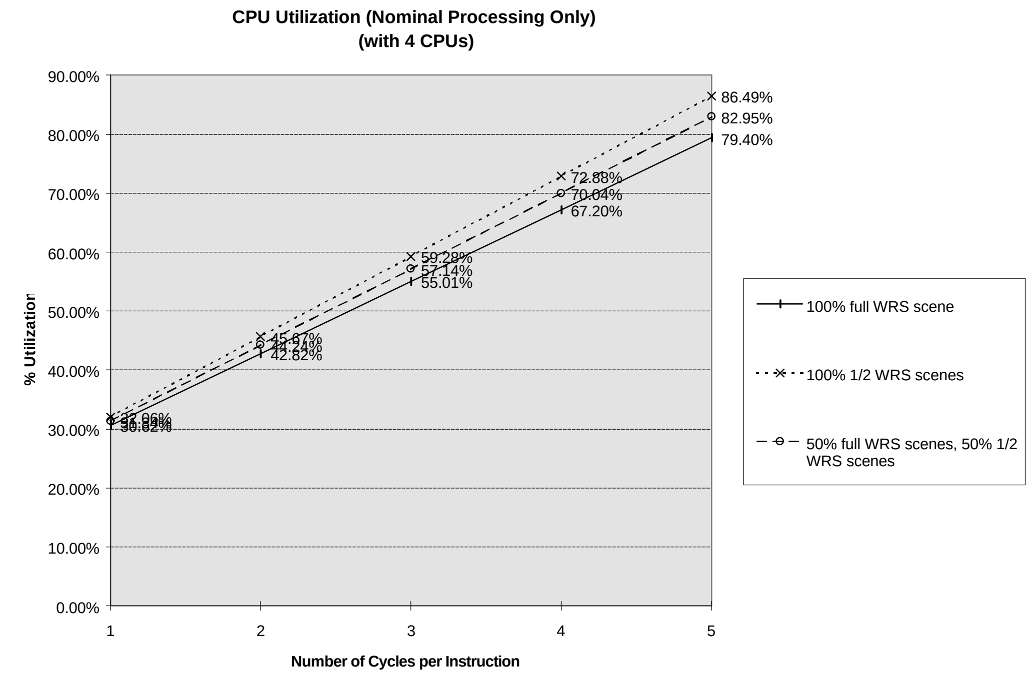


Figure 6–1. CPU Utilization As a Function of Scene Size and Number of CPU Cycles per Instruction (Nominal Processing Only)

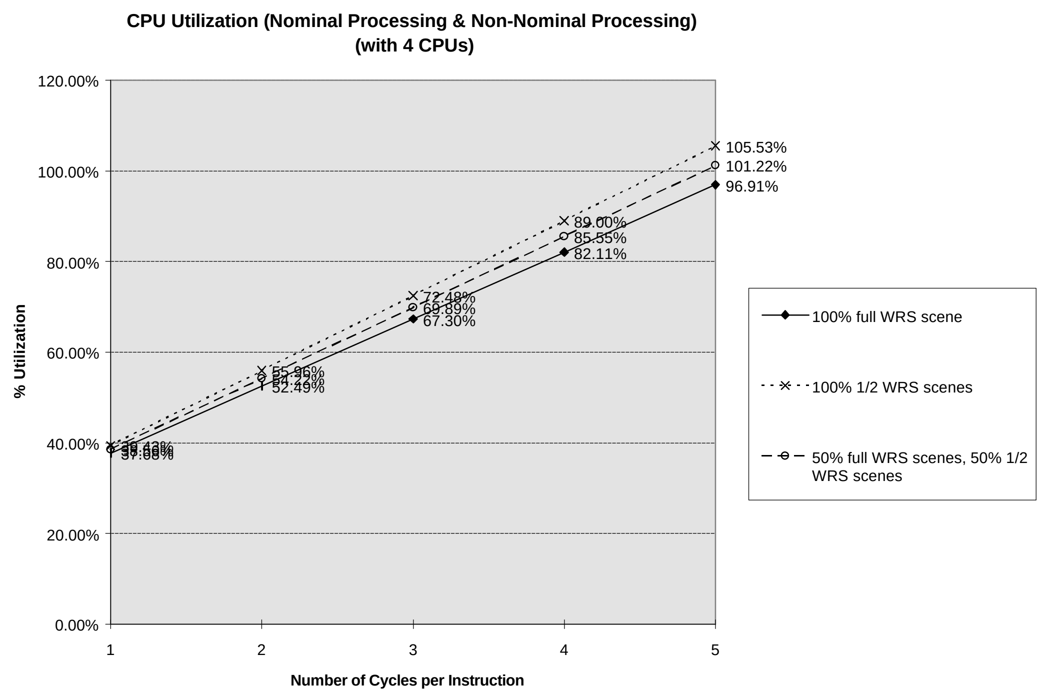
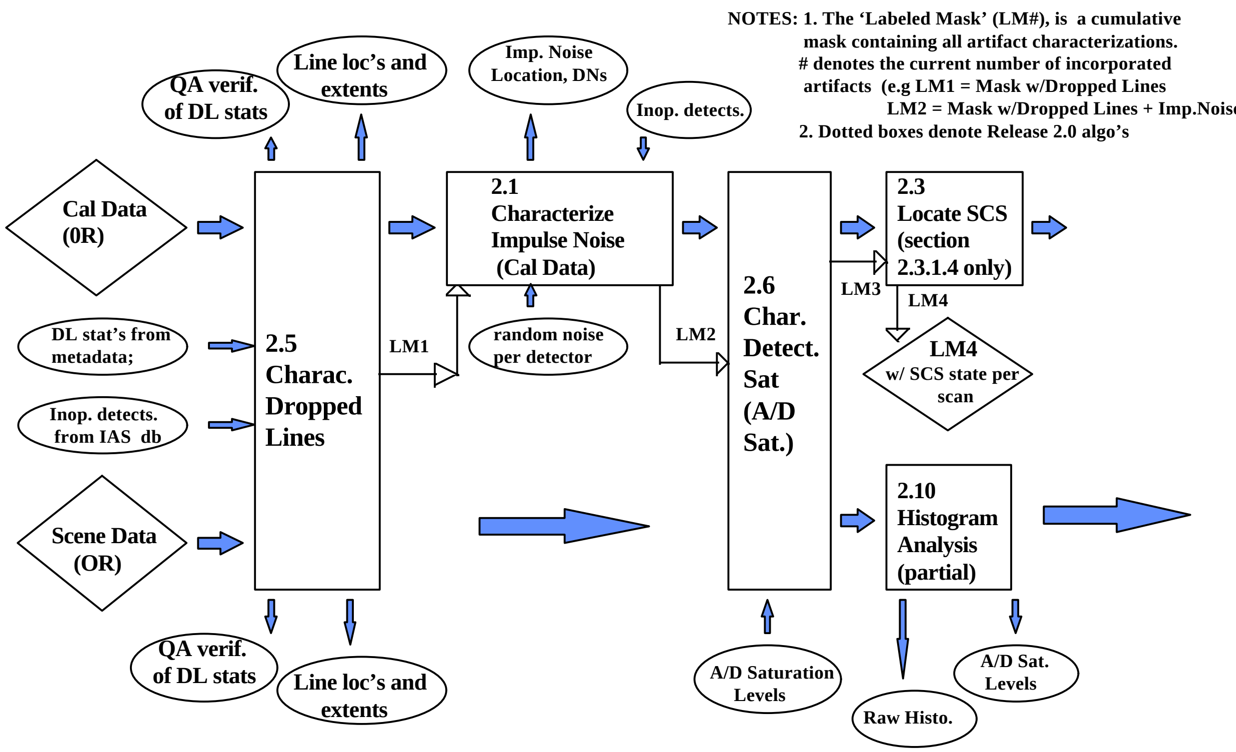


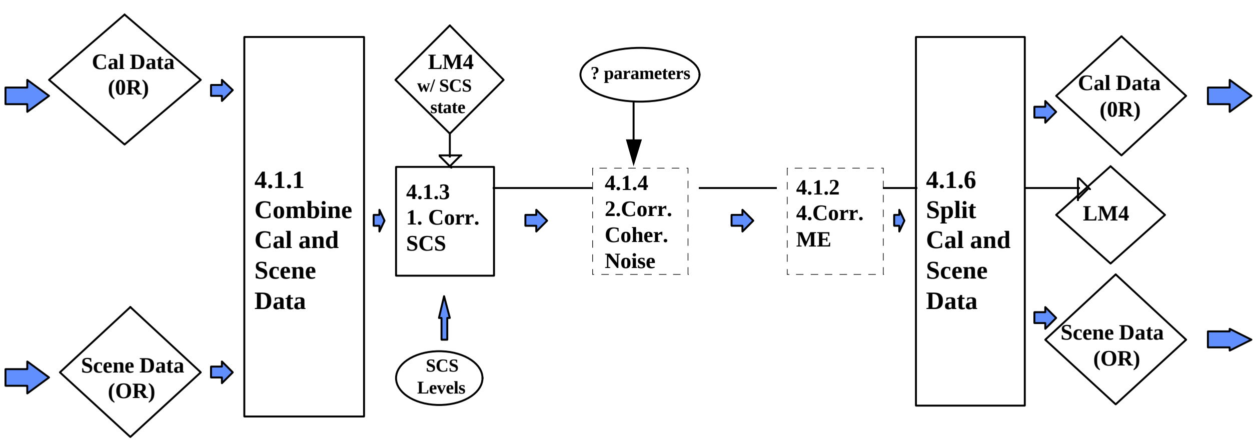
Figure 6–2. CPU Utilization As a Function of Scene Size and Number of CPU Cycles per Instruction (Including Non-nominal Processing)

Appendix A. Radiometric Processing Process Flow



Level 1R Processing (Day Scene)
Release 1.0
Step 1. 0R Radiometric Characterization

(update 3/4/97)

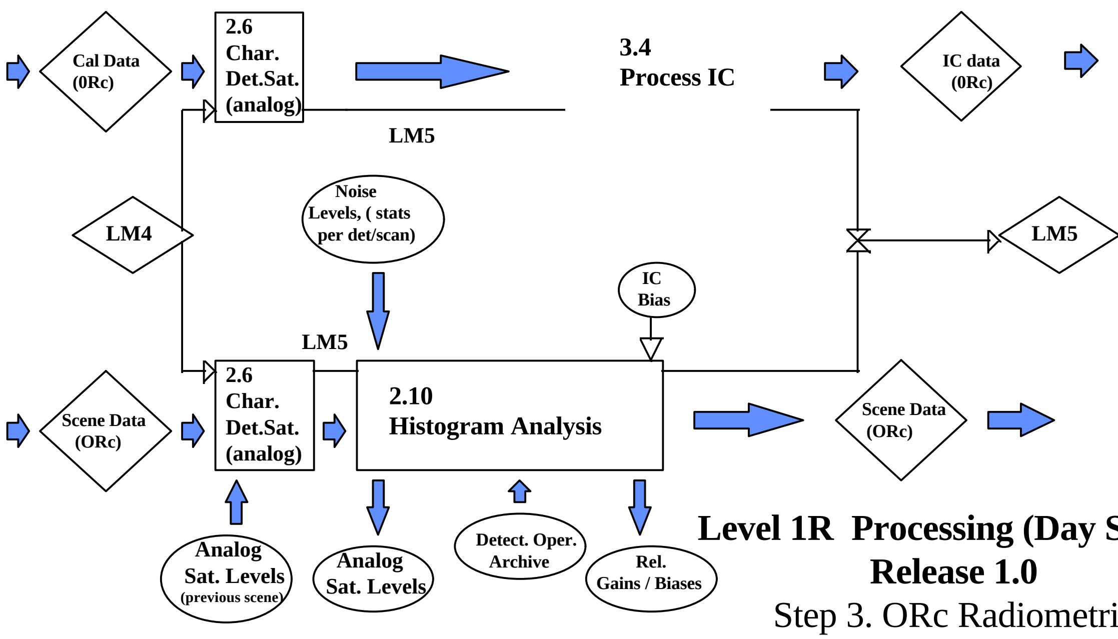


Note: Dotted boxes denote Release 2.0 algorithms

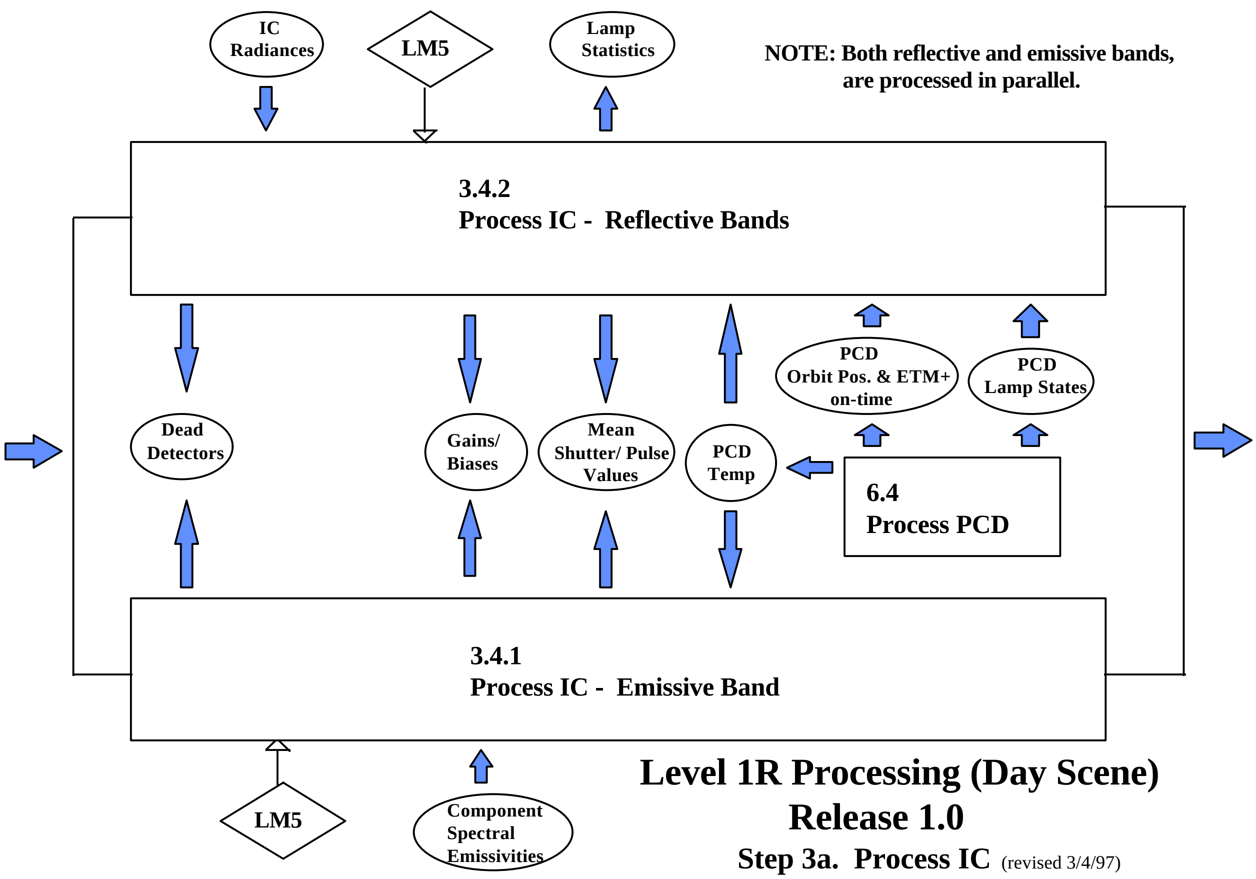
Level 1R Processing (Day Scene)
Release 1.0
Step 2. Pre-1R Correction

(revised 3/4/97)

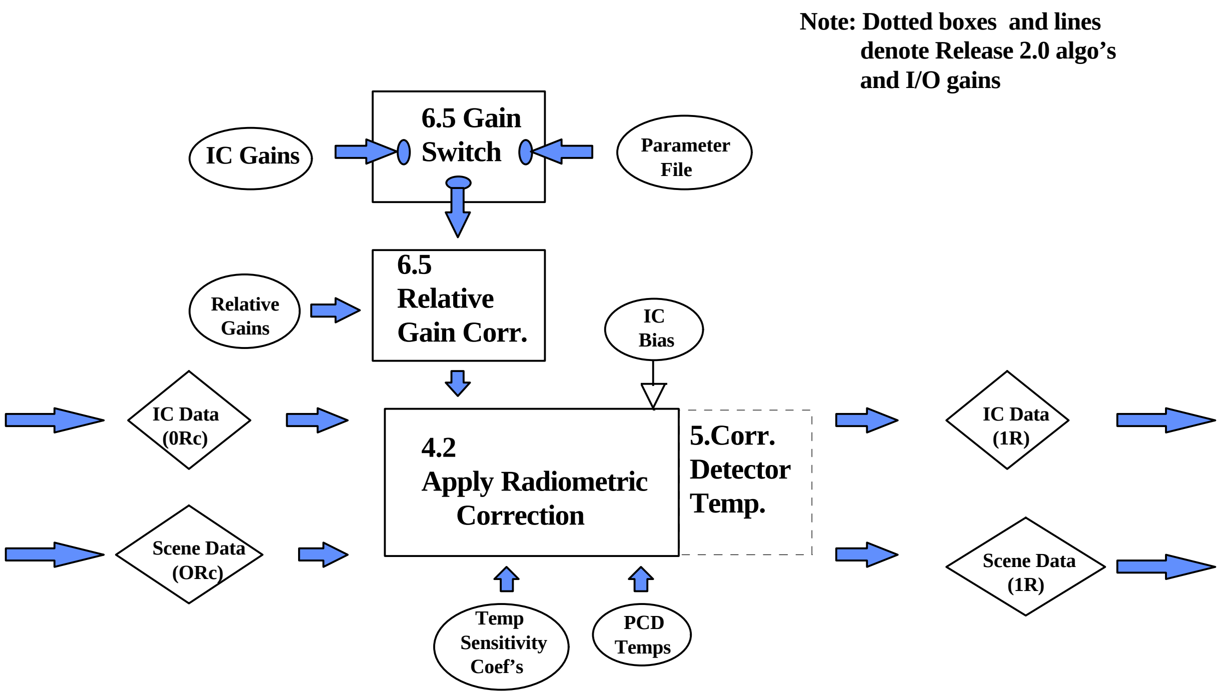
Notes: 1. Dotted boxes denote Release 2.0 algo's
2. For algorithm "3.4 Process IC", see detailed flow in Step 3a.



Level 1R Processing (Day Scene)
Release 1.0
Step 3. ORc Radiometric Characterization/Calibration
(revised 3/4/97)



Level 1R Processing (Day Scene)
Release 1.0
Step 3a. Process IC (revised 3/4/97)

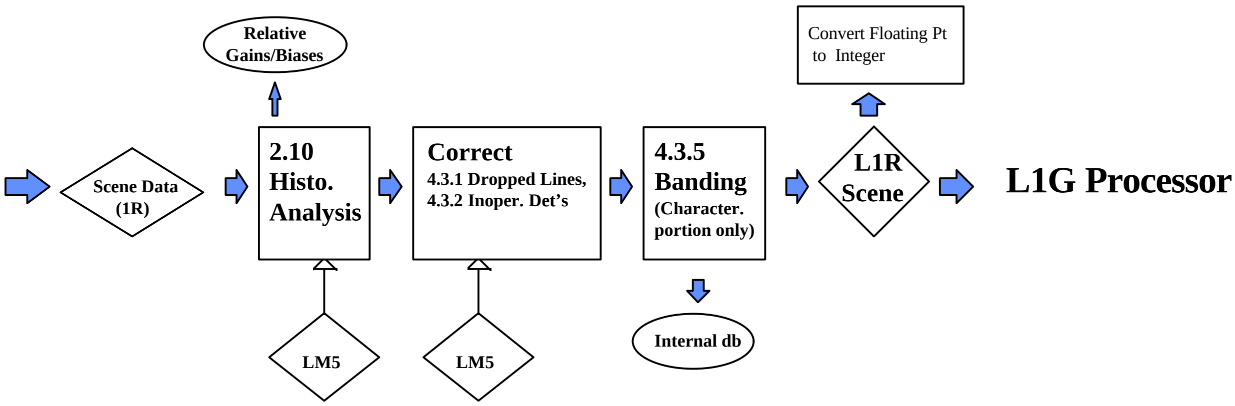


Level 1R Processing (Day Scene)
Release 1.0

Step 4. 1R Correction

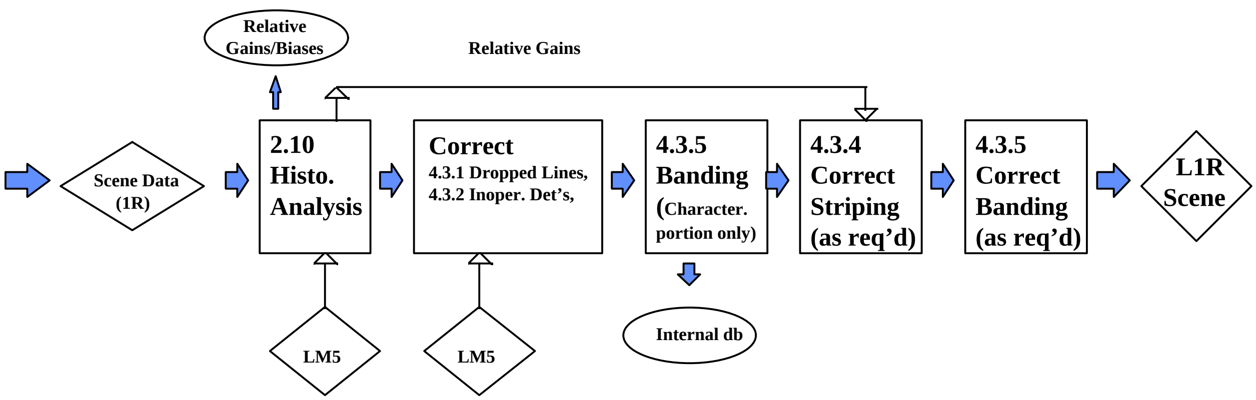
(revised 3/4/97)

Evaluation and Analysis



Level 1R Processing (Day Scene)
Release 1.0

Step 5.0 1R Radiometric Characterization/Correction
(Scenario 1: No Correction for Striping and Banding Effects)
(revised 3/4/97)



Level 1R Processing (Day Scene)
Release 1.0

Step 5.0 1R Radiometric Characterization/Correction
(Scenario 2: Correct for Striping and Banding Effects IFF Necessary)
(revised 3/4/97)

Appendix B. QASE Simulation Model

Although the spreadsheet model provides accurate mean utilizations and mean service times, it cannot provide information about the dynamic character of the LPGS. In particular, the CPU, FDDI, RAID, and other system resources may become overutilized for protracted times during the normal daily cycle of operations, even though the average values for these components appear to be reasonable. To examine this possibility, a discrete-event simulation model was built.

B.1 Problem Statement

For purposes of this analysis, LPGS performs two types of operations on scene data: nominal processing and anomaly analysis processing. Nominal processing executes the following activities serially:

1. Data ingestion
2. Radiometric processing
3. Geometric processing
4. Product formatting
5. Product delivery

All bands are processed at each stage before moving to the next stage. The baseline case assumes that 25 scenes receive nominal processing over a 24-hour period, and that this processing can be started uniformly over that planning horizon.

In about 10 percent of the cases, quality assurance checks detect a potential problem with the products. When that happens, anomaly analysis executes a set of procedures to identify and correct the problem. Once the problem has been diagnosed, the scene is rerun with the new parameters before it is distributed to LPGS customers. These steps can include the following:

1. Running a set of LPGS benchmarks
2. Executing diagnostics on the offending scene
3. Reprocessing the data with corrected information
4. Delivering the LPGS products.

Benchmarking, diagnostics, and reprocessing each require resources at the same levels as the radiometric processing, geometric processing, and product formatting portions of the nominal processing, since much of the same software is exercised on data sets of equivalent sizes.

To complicate matters, management plans to have staff present only during the prime shift. Since anomaly analysis requires manual inspection of the data, this means that all anomalous cases need to be examined during that time.

One strategy is to begin the analysis of a day’s worth of cases at the beginning of each prime shift. A second strategy is to have an analyst present at each shift, and to analyze the cases uniformly at the rate of one anomaly analysis thread activation per shift. These two strategies are referred to as the Prime Shift and Uniform scenarios, respectively.

To assess the effects of these strategies, management wants to compare the loadings and turnaround times for nominal processing and anomaly analysis over a 5-day period. Utilizations are to be computed both in the long-term sense of the spreadsheet and over 10-minute sampling intervals.

Service time measurements include the smallest, largest, and average service times over the 5-day sampling period. The number of nominal and anomaly thread activations and completions is also desired.

The total number of arrivals for each day is set at 25. For the nominal case, this means that there are 25 scenes that begin nominal processing, 3 scenes that require reprocessing, and no cases that require anomaly analysis. In the case of anomaly analysis, there are three scenes that require anomaly analysis. Either all three scenes start at once each day (at the same time), or the scenes are started uniformly over a 24-hour period.

B.2 Simulation Model

To assess the dynamic characteristics of the LPGS, a simulation model of the system using the QASE RT system performance modeling package was constructed. QASE RT, sold by Advanced System Technology, Inc. (AST), was originally developed under the auspices of Code 510. The Nominal scenario, shown in Figure B–1, ingests 25 WRS scenes per day from the EDC DAAC, performs radiometric and geometric processing, and transmits the Level 1 products back to the EDC DAAC.

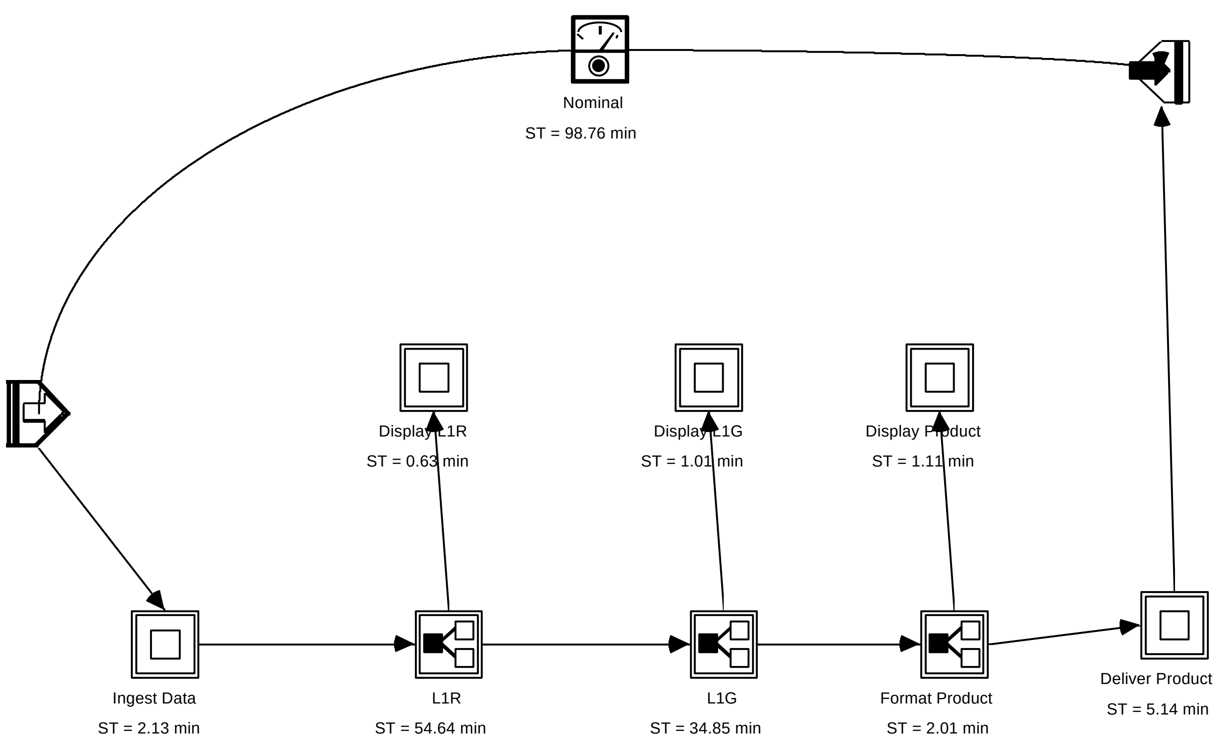


Figure B–1. LPGS Nominal Processing Flow

Figure B–2 shows anomaly analysis processing. Three scenes per day exhibit anomalous characteristics and must be examined and reprocessed. Because the data must be examined pixel-by-pixel, both nominal and anomalous processing are computing-intensive operations.

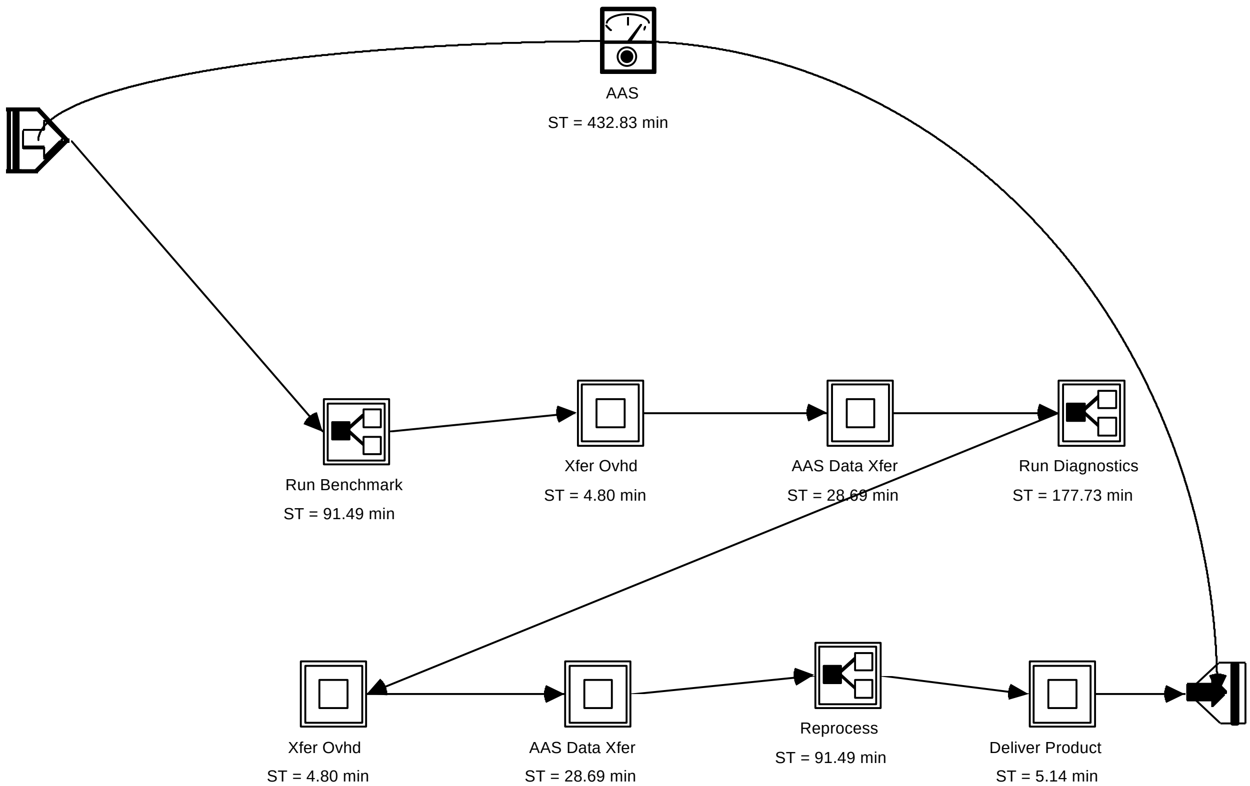


Figure B–2. LPGS Anomaly Processing Flow

LPGS system performance was analyzed by simulating the effect of the workload on the system hardware and software architecture. The LPGS workload is defined by the times between the processing of scenes was initiated. Only a critical subset of the hardware was modeled.

The diagnostic run requires the analyst at the Anomaly Analysis Subsystem (AAS) workstation to review the output of the run. The uncertainty in the amount of time required for the analyst to identify and resolve the problem is represented in the analyst activities software module type by the set of statements:

Analyst Activities

```
Loop Poisson(Analyst_Cycles_per_Scene) times
    Delay exponential(Analyst_Think_Time_Minutes) min
    Get 1 instances of AAS Analyst Data
    Execute exponential(Analyst_Minst_per_Cycle) M Instructions
End Loop
```

where it has been assumed that the analyst loops through the sequence eight times (one for each band) examining data and spending 10 minutes examining the data each time. The analyst retrieves an amount of data equal to the average overall data set sizes, and executes a number of instructions commensurate with retrieving the data from the AAS disk. The think time and instruction estimate are assumed to be exponentially distributed, and the loop is traversed a Poisson number of times.

B.3 Results

The simulation model provides both summary and dynamic results.

B.3.1 Summary Results

Table B–1 summarizes the response times by workload scenario. The service time column shows the expected service time for the thread without any queuing effects.

Table B–1. Comparative Response Times by Type of Processing

Comparative Response Times by Type of Processing				
Response Time	**Service Time**	**Nominal Nom=28/Day AAS = 0/Day**	**Prime Shift Nom=25/Day AAS = 3/Day**	**Uniform Nom=25/Day AAS = 3/Day**
Nominal				
Minimum	N/A	99.78 min	99.14 min	99.14 min
Mean	98.76 min	100.46 min	107.51 min	101.17 min
Maximum	N/A	101.32 min	167.21 min	120.28 min
Started	N/A	140	125	125
Completed	N/A	138	123	123
Anomaly Analysis				
Minimum	N/A		470.19 min	406.15 min
Mean	432.83 min	Not Applicable	514.38 min	445.18 min
Maximum	N/A		557.69 min	508.09 min
Started	N/A		15	15
Completed	N/A		12	14

The response time for the anomaly analysis processing includes benchmark run, transferring benchmark results to the AAS workstation, quick visual assessment of the benchmark results, diagnostic run, transferring diagnostic results to the AAS workstation, visual assessment of the diagnostic results, reprocessing the data with corrected parameters, and delivering the LPGS product.

From Table B–1, it can be seen that starting all three anomaly scenes at the beginning of the prime shift introduces significant queuing effects into the system. The mean and maximum response times are significantly higher than for either the Nominal or Uniform scenarios. In particular, the mean response time for the anomaly processing thread is nearly 70 minutes greater for the Prime Shift case than for the Uniform case. AAS is not executed for the Nominal case. Note also that in the Prime Shift case, none of the arrivals in the last bulk arrival completed before the end of the simulated 5-day period.

Table B–1 indicates that spreading AAS processing over three shifts has the least impact on both Nominal and AAS turnaround times.

Another strategy to balance the workload during the prime shift is to reduce or curtail nominal processing of new scenes until anomaly analysis is complete. This action increases the resource loads in the remaining two shifts. Although explicit simulation runs have not been made for this scenario, such a strategy would make optimum use of available LPGS labor on a daily basis because of the intensive human interaction required for anomaly analysis.

Table B–2 displays the capability and offered load for each of the critical LPGS hardware devices. The offered load of a device is the average amount of work (instructions to execut ion of data to transfer) presented to a device relative to the device's capacity. The offered load ignores contention and synchronization. The offered load is the long-run utilization of the LPGS devices.

Table B–2. Offered Load for Critical Hardware Items

Hardware Item	Capability	Nominal	Prime Shift	Uniform
SGI Origin 2000	4 CPUs @ 90.675 MIPS	42.73%	52.69%	52.69%
RAID (with visual assessment included)	70.0 MBPS	13.58%	16.39%	16.39%
Console	75.0 MIPS	3.48%	3.48%	3.48%
FDDI	60 Mbps	9.37%	15.84%	15.84%
AAS Workstation	75.0 MIPS	0.00%	0.45%	0.45%
AAS Disk	20.0 MBPS	0.00%	3.37%	3.37%

The processor speed of the SGI Origin 2000 was determined as

SGI_Speed_MIPS = (195.0 MHz / 2.0 cycles per instruction) x (1- .07 derating factor).

Some of the entries in Table B–2 vary slightly from the spreadsheet results because console display processing and associated RAID I/O are included in the simulation model. There are also Small differences exist between the spreadsheet and the simulation model in service times because of the way in which service times were calculated.

The offered load of the Prime Shift scenario is identical to that of the Uniform scenario because the overall arrival rate of the two is the same, even though the manner in which AAS processing is scheduled is very different.

The offered load on the console is the same across all three scenarios for the same reason. Console display processing is activated at the same rate for each.

B.3.2 Nominal Scenario Dynamic Results

Figure B–3 shows a plot of response times against the time at which the processing was completed.

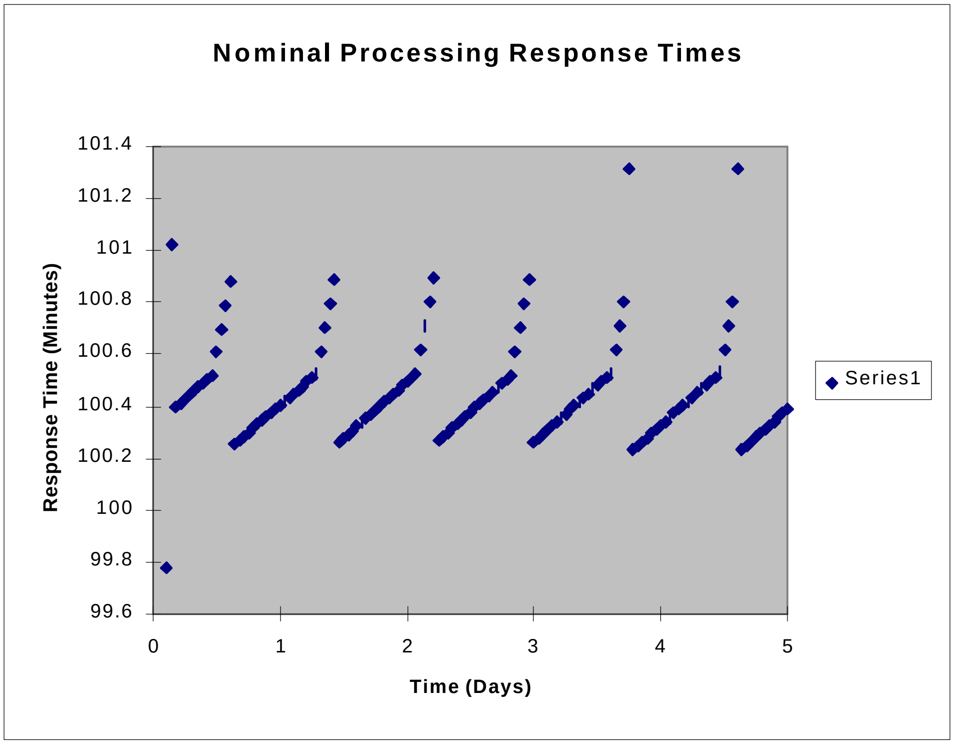


Figure B–3. Nominal Processing Response Times

Figure B–4 shows the utilization time series of the SGI Origin 2000 processor. Following a brief "warm-up" period at the beginning of the simulation run, the utilization remains within a fairly narrow range. The periodic nature of the waveform is due to the periodicity with which new scene nominal processing is initiated. Figure B–5 shows the utilization of the display console processor. Figure B–6 shows the RAID bandwidth utilization. Note how the RAID utilization is synchronized with both the SGI Origin 2000 utilization and the console utilization. This is because both are driven by the same software flows.

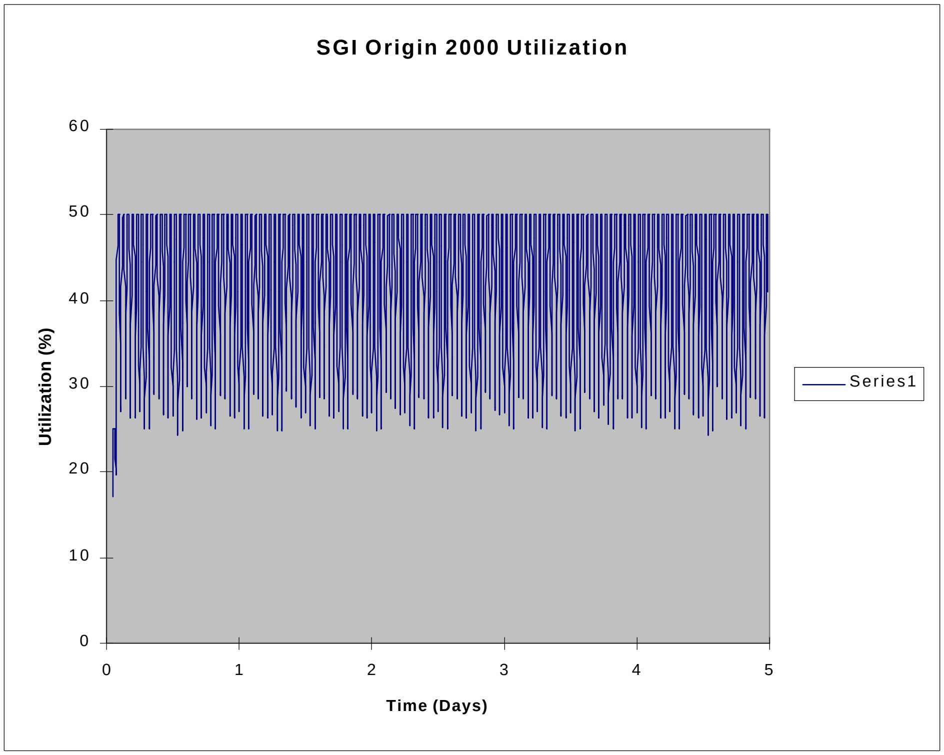


Figure B–4. SGI Origin 2000 Processor Utilization (Nominal Scenario)

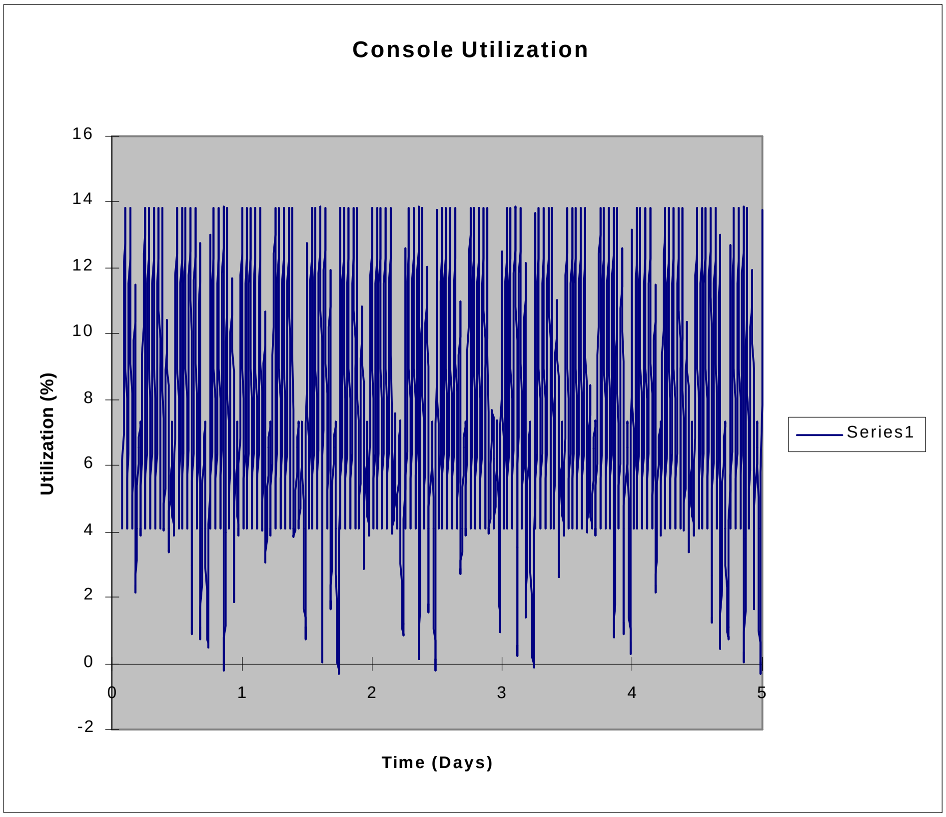


Figure B–5. Display Console Processor Utilization (Nominal Scenario)

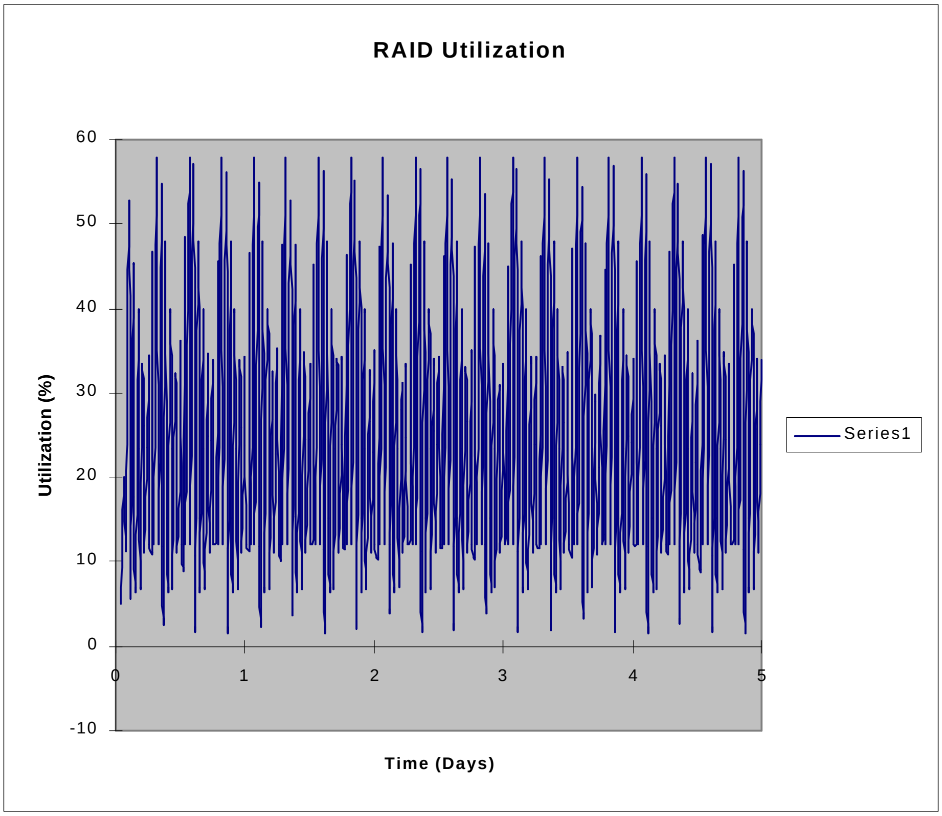


Figure B–6. RAID Bandwidth Utilization (Nominal Scenario)

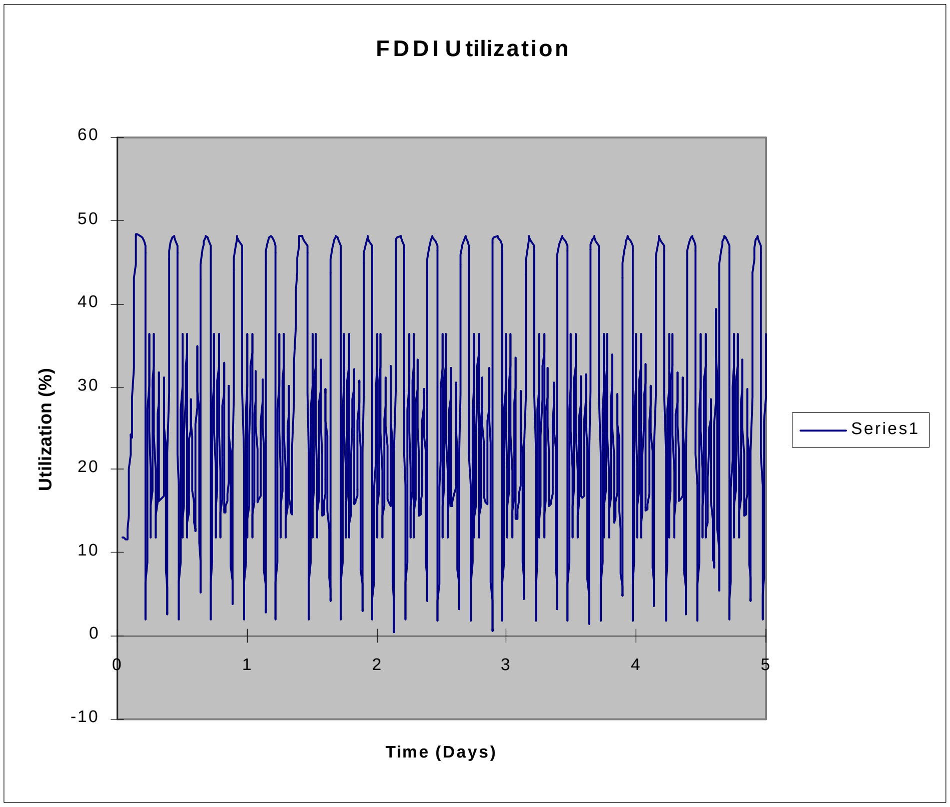


Figure B–7. FDDI Utilization (Nominal Scenario)

B.3.3 Prime Shift Dynamics Results

In contrast to the relatively smooth flow of operations displayed by the Nominal case, the Prime Shift scenario exhibits a periodic series of shocks due to the bulk arrival of three AAS requests at the beginning of each prime shift. Response times for Nominal processing are disrupted, and several devices become saturated.

Figure B–8 shows the response times for Nominal and AAS processing. In some cases, the scale of the figure does not separate the individual AAS response times. Notice the "blistering" effect that the bulk arrival of AAS requests has on the nominal response times.

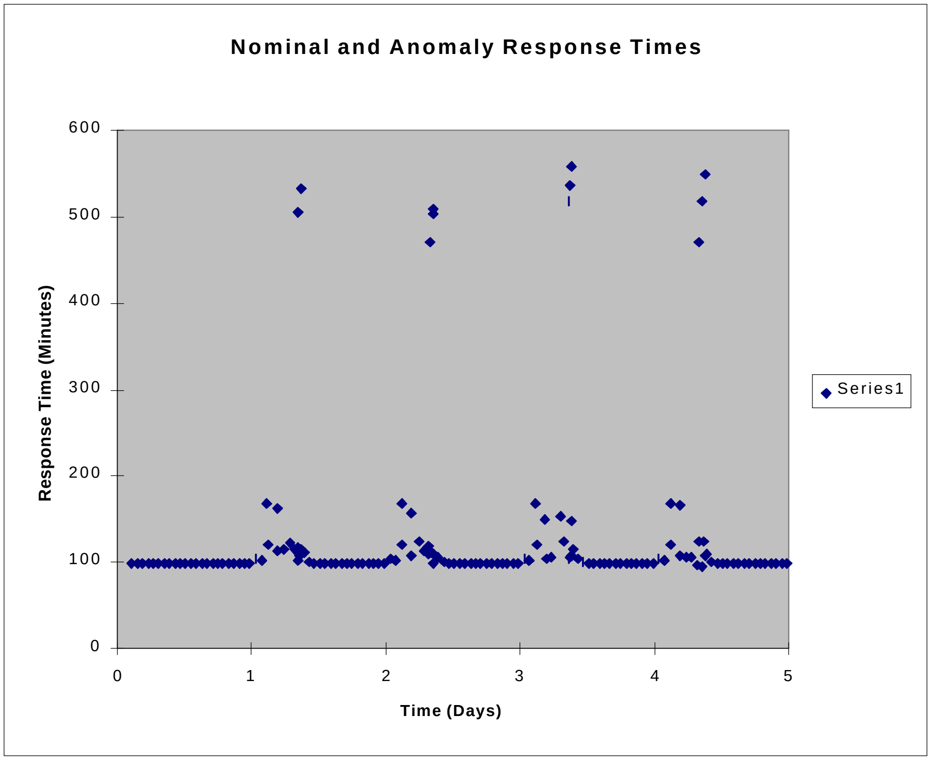


Figure B–8. Response Times for Nominal and AAS Process Flows

Figure B–9 shows part of the reason for the disruption of response times. The SGI Origin processor becomes saturated for extended periods of time when this scheduling approach is used. Figure B–10 shows the corresponding display console utilization. The pattern is not as prominent. Figure B–11 shows the RAID bandwidth utilization. Although the scheduling effect is significant, it extends for only brief periods compared to the SGI Origin 2000. The bulk-arrival effect saturates the FDDI utilization time series for brief periods of time as Figure B–12 shows. The effect of bulk arrivals is clearly apparent, along with the quiescent time between prime shifts.

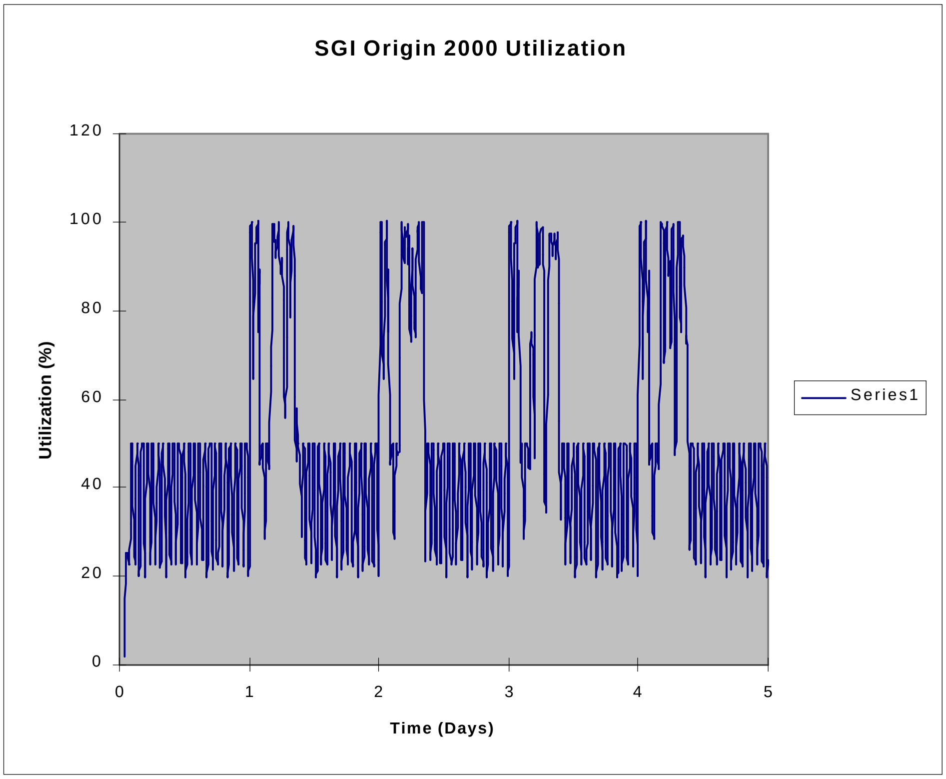


Figure B–9. SGI Origin 2000 Processor Utilization (Prime Shift Scenario)

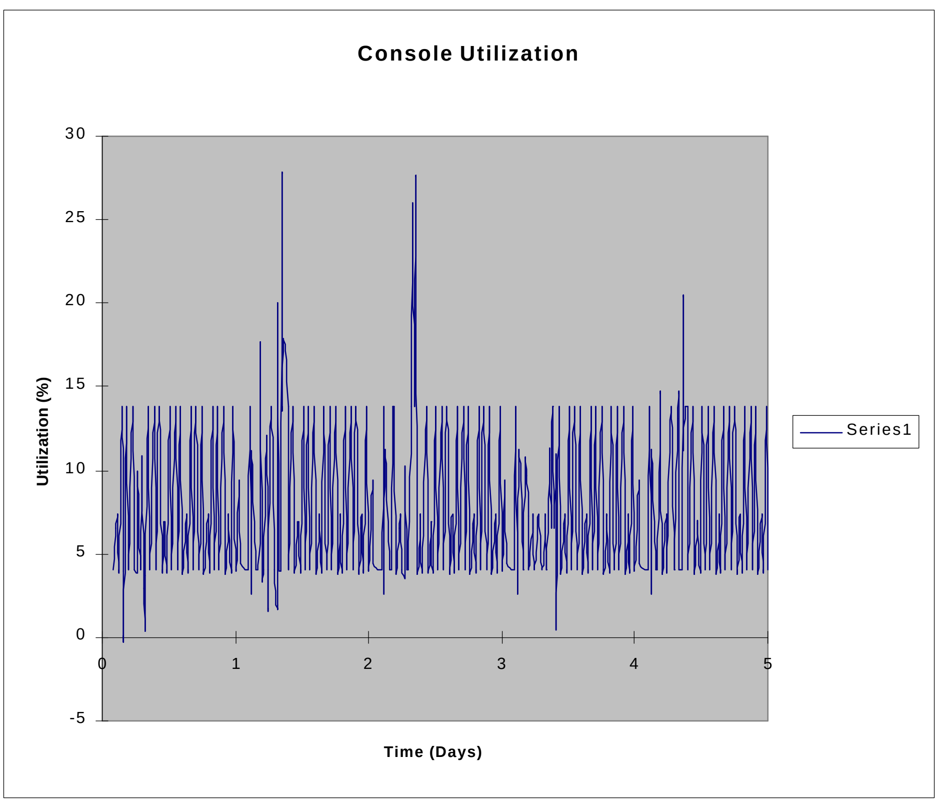


Figure B–10. Display Console Processor Utilization (Prime Shift Scenario)

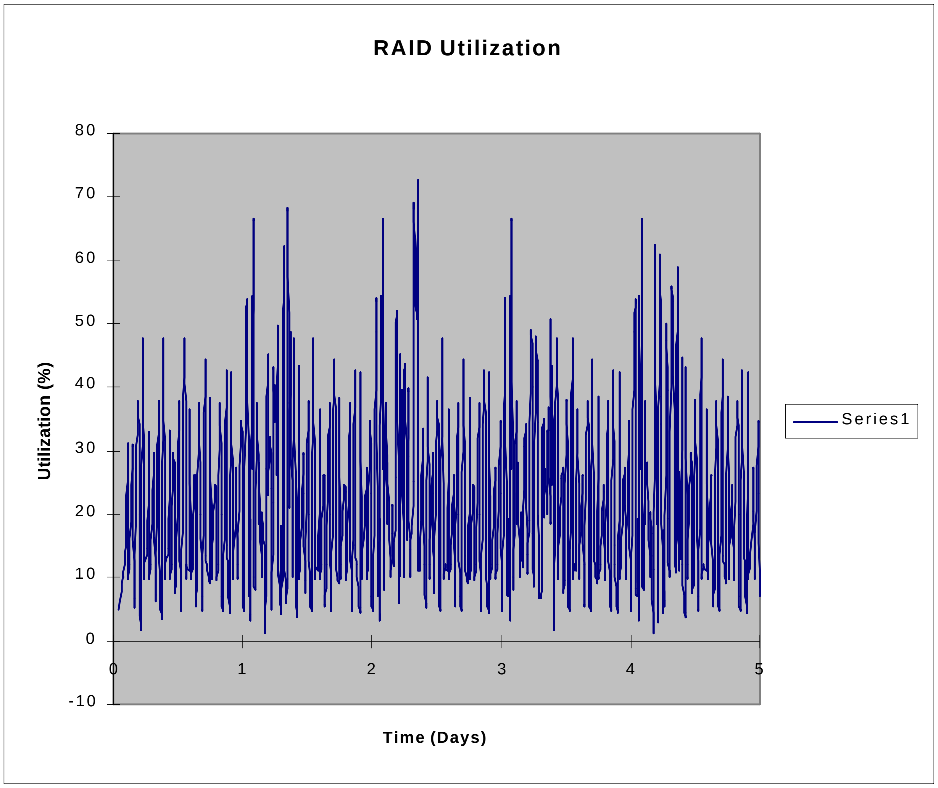


Figure B–11. RAID Bandwidth Utilization (Prime Shift Scenario)

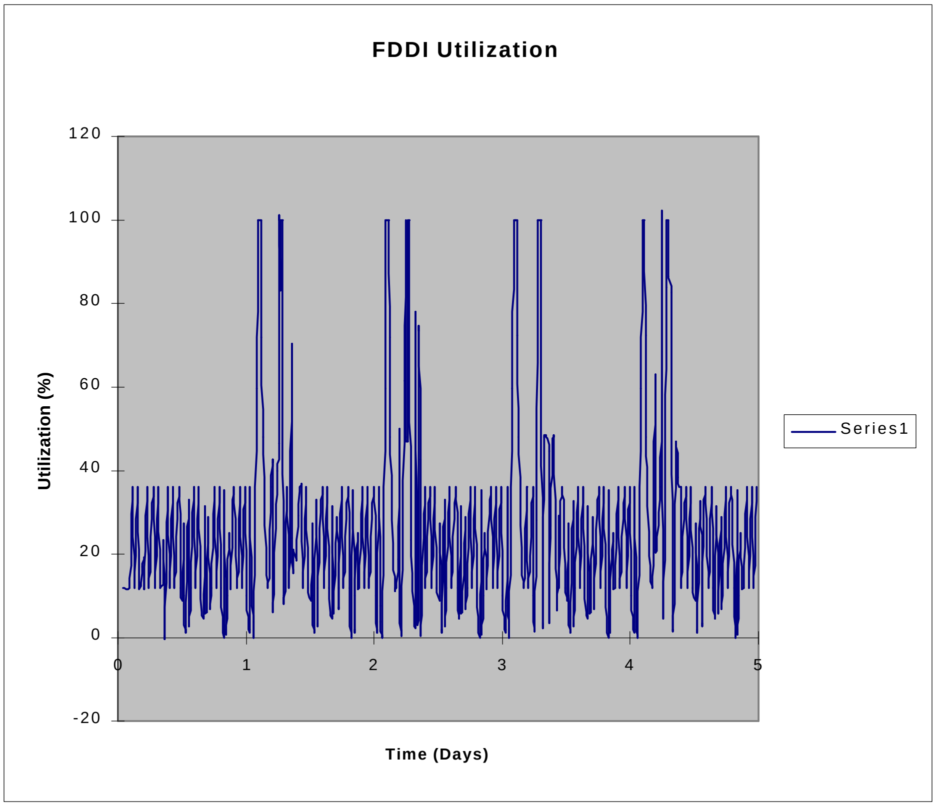


Figure B–12. FDDI Utilization (Prime Shift Scenario)

B.3.4 Uniform AAS Dynamic Results

In contrast to the Prime Shift scenario, processing a single AAS sequence per shift smoothes the utilization and response times considerably. Figure B–13 shows the response time graph, and Figure B–14 shows the SGI Origin 2000 processor utilization. The step function, which the SGI utilization shows at the beginning of the simulation, is due to the arrival of the first AAS request. Figure B–15 shows the console utilization, and Figure B–16 shows the RAID bandwidth utilization for the Uniform scenario. Although the effect on the utilizations of all of the devices can be seen, only the FDDI, as shown in Figure B–17, becomes saturated briefly during periods of AAS processing.

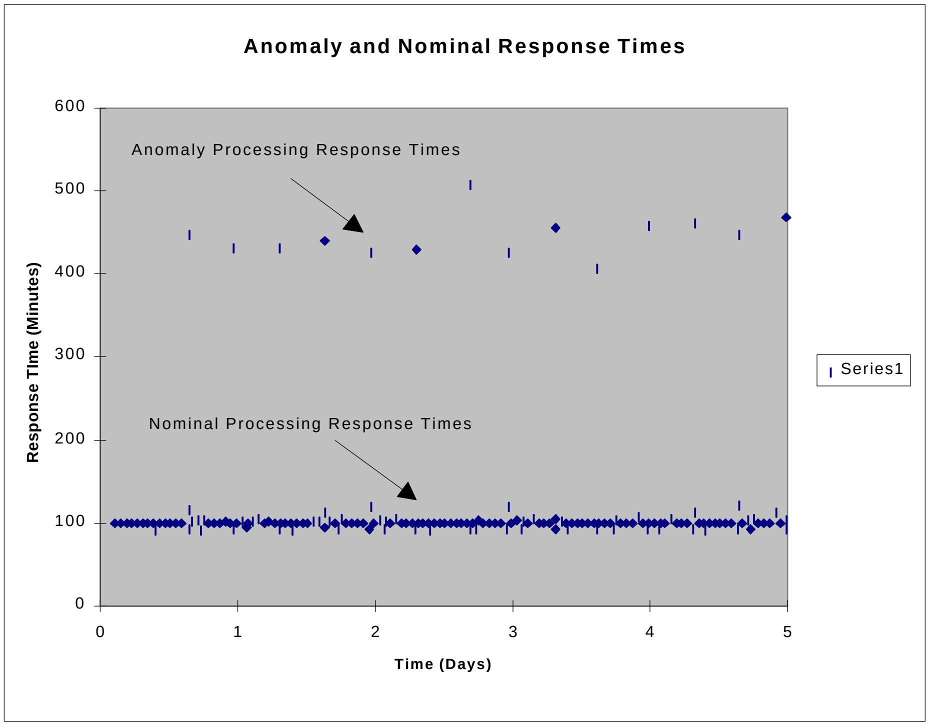


Figure B–13. Nominal and AAS Response Times

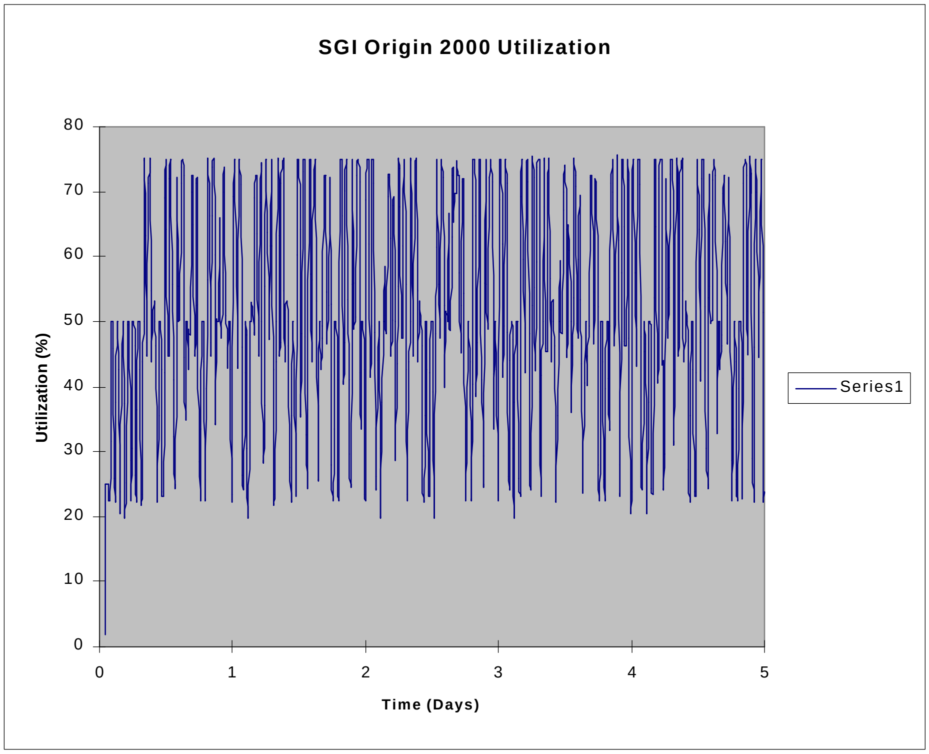


Figure B–14. SGI Origin 2000 Processor Utilization (Uniform Scenario)

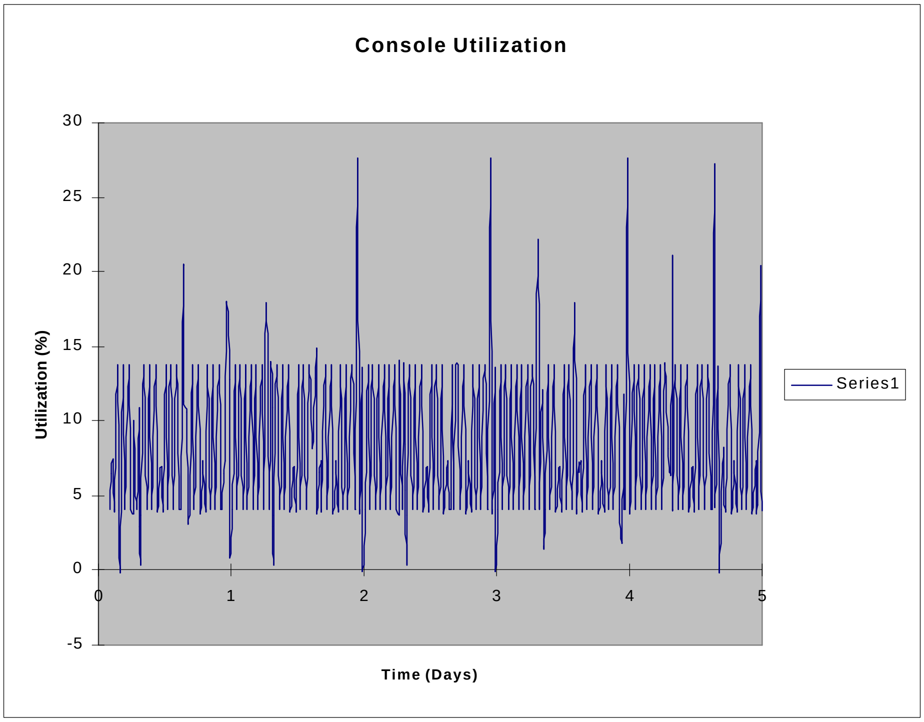


Figure B–15. Display Console Processor Utilization (Uniform Scenario)

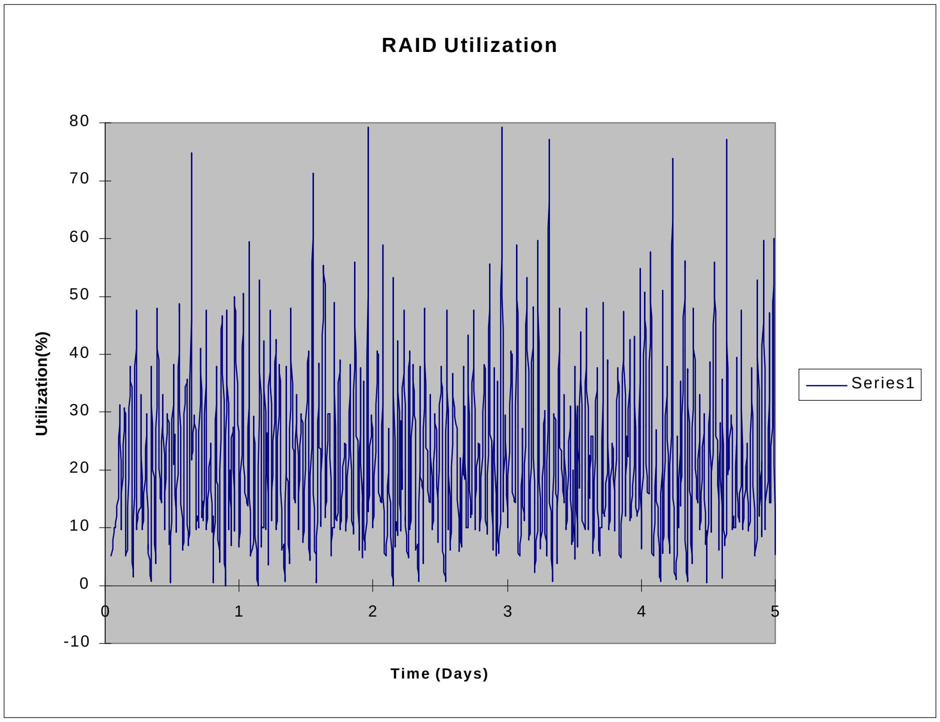


Figure B–16. RAID Bandwidth Utilization (Uniform Scenario)

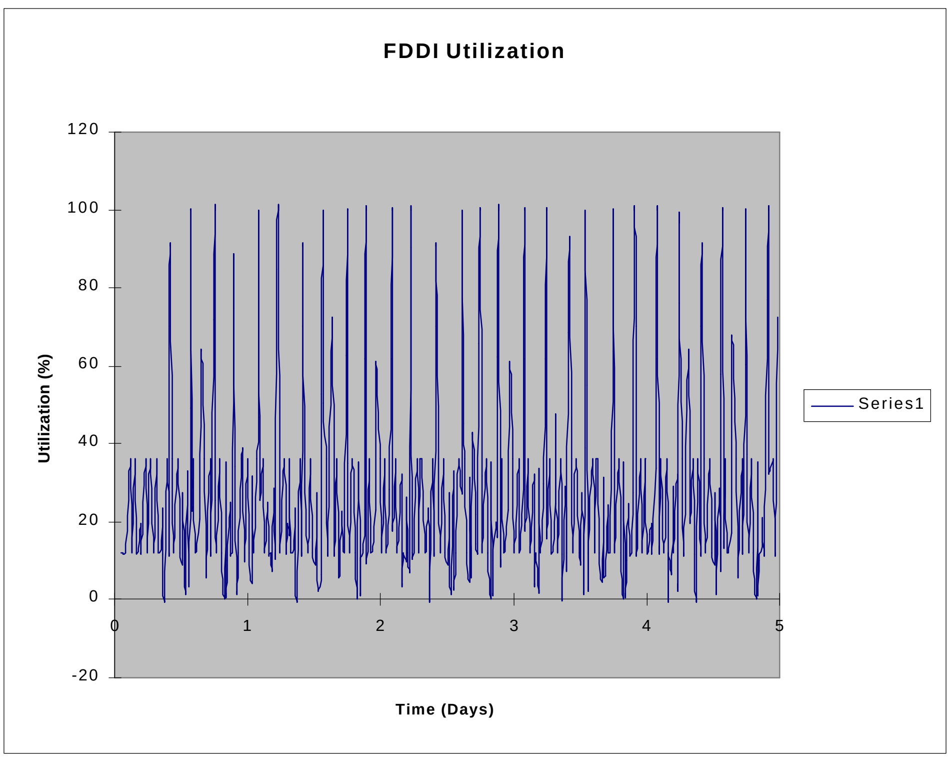


Figure B–17. FDDI Utilization (Uniform Scenario)

Acronyms and Abbreviations

AA	anomaly analysis
AAS	Anomaly Analysis Subsystem
AST	Advanced System Technology, Inc.
CPU	Central Processing Unit
DAAC	Distributed Active Archive Center
ECS	EOS Core System
EDC	EROS Data Center
EGS	ESDIS Ground System
ENVI	Environment for Visualizing Images
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EROS	Earth Resources Observation System
ESDIS	Earth Science Data and Information System
ETM+	Enhanced Thematic Mapper Plus
F&PRS	functional and performance requirements specification
FDDI	fiber-optic data distribution interface
FIFO	first in-first out
GB	gigabyte
HWCI	hardware configuration item
IAS	Image Assessment System
IDL	Interactive Data Language
I/O	input/output
L0R	Level 0 radiometrically corrected
L1	Level 1
L1G	Level 1 geometrically corrected
L1R	Level 1 radiometrically corrected
LPGS	Level 1 Product Generation System
MB	megabyte
MFLOPS	Million Floating Point Operations

MHz	megahertz
MSCD	mirror scan correction data
PCD	payload correction data
QA	quality assessment
QASE RT	Quantitative Case for Reliability and Timing
RAID	redundant arrays of independent disks
SCSI	small computer system interface
SGI	Silicon Graphics, Inc.
WRS	Worldwide Reference System